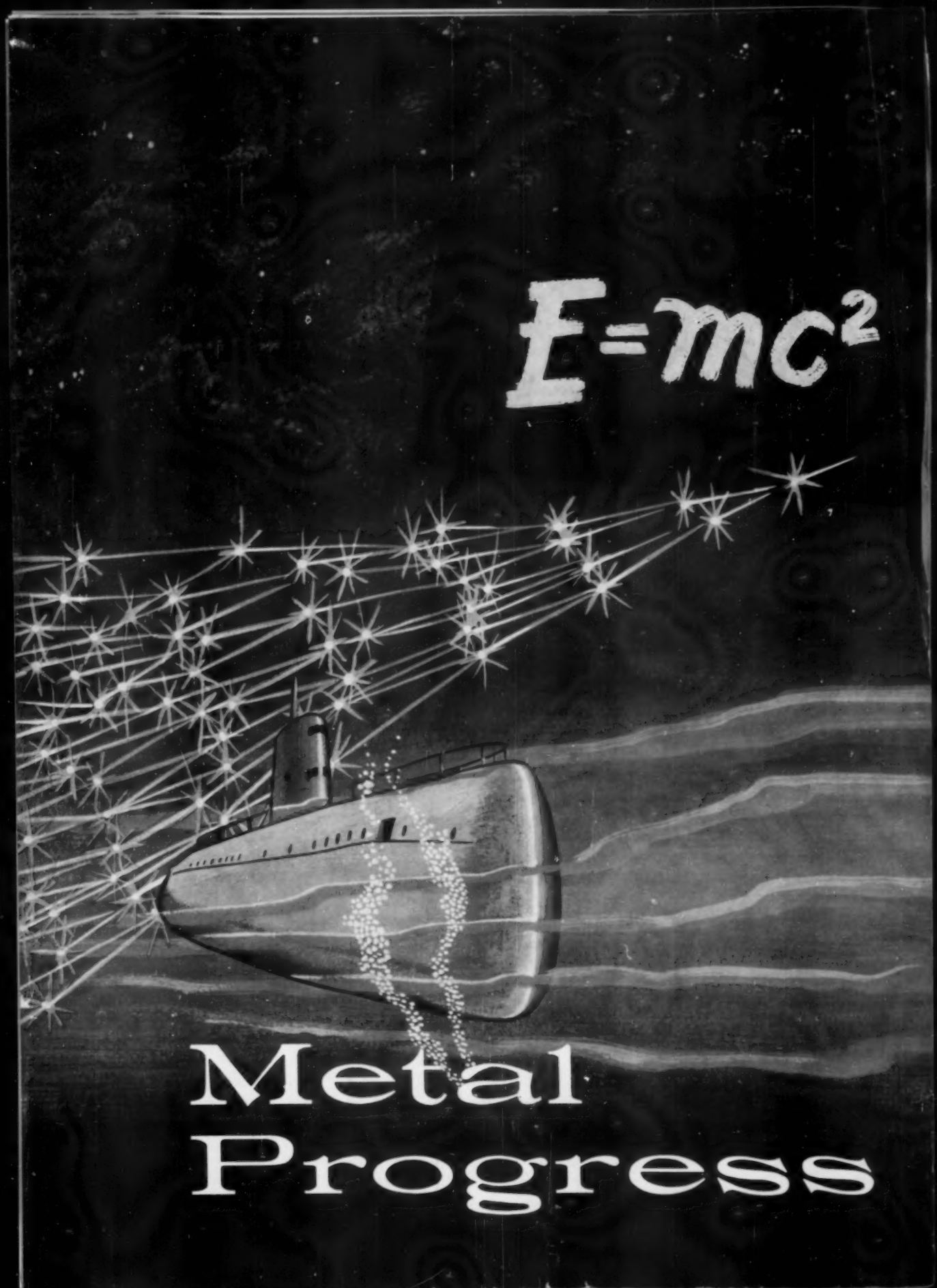
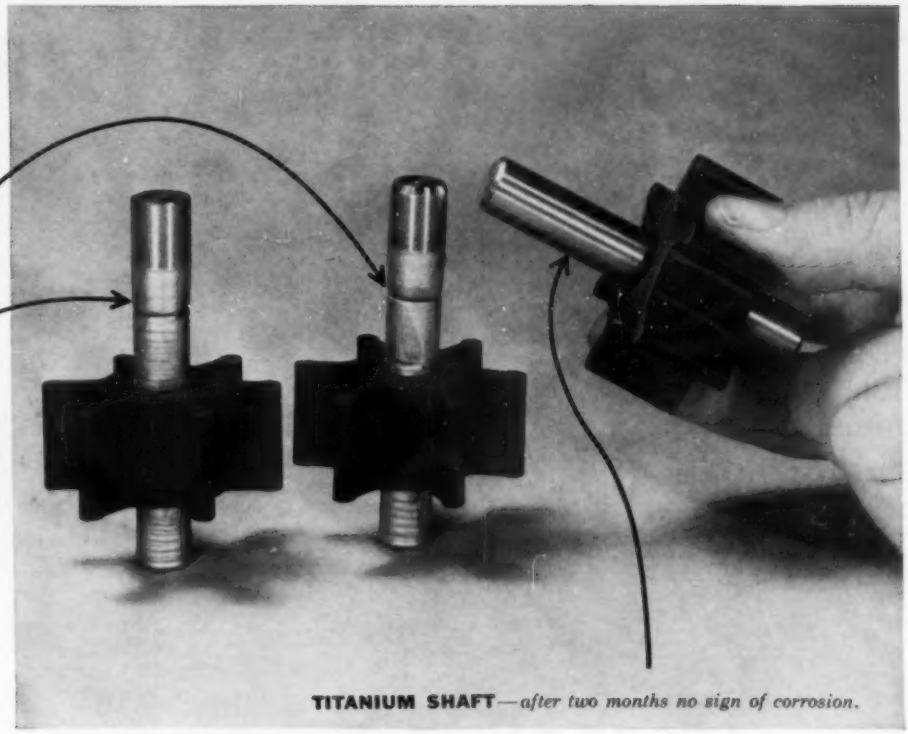


Metal Progress

Progress with **TITANIUM**



SHAFTS WHICH FAILED AFTER 45 MINUTES. *Both are made of premium metals, one ferrous, one non-ferrous.*

TITANIUM SHAFT—*after two months no sign of corrosion.*

TITANIUM PUMP SHAFT LASTS

...where other metals corroded in 45 minutes

The problem was to pump ferric chloride, an acid used in etching printed circuits in electronics manufacturing. Jabsco Pump Company, of Burbank, California, sought to develop a pump to handle this highly corrosive acid, and replace batch handling.

Premium metals were tried for the pump shaft (the impeller is neoprene and the casing is plastic), but corrosion around the seal almost immediately led to leakage and failure. A glass shaft did not have sufficient strength. Then, using Mallory-Sharon commercially pure titanium for the shaft, the problem was solved—permanently. Titanium has outstanding resistance to chlorides.

The cost figures here are illuminating. The pump with the titanium shaft cost about double the pump with the ferrous metal shaft . . . and about the same as the pump with the other non-ferrous metal shaft (because of machining difficulty with the latter). So first cost of titanium is lower than you may think. And titanium paid for itself in *90 minutes*.

Let us help you apply titanium to your corrosion problems . . . our service engineering group will be glad to assist. For information, write Dept. F-6.

TYPICAL PRESENT APPLICATIONS OF TITANIUM

Anodizing racks	Impellers
Condenser inserts	Piping
Filters	Process vessels
Heat exchangers	Steam jet diffusers

MALLORY Ti SHARON

MALLORY-SHARON TITANIUM CORPORATION · NILES, OHIO

Producers of titanium and titanium alloy sheet, strip, plate, rod, bar, billets

Metal Progress

Volume 71, No. 6

June . . . 1957

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Engineering Articles

Metallurgical Aspects of Calder Hall, by Tom Bishop 65

The first nuclear power plant in the world to produce electricity for general use on a large scale has gone into operation smoothly and satisfactorily, and is fulfilling all the best hopes of its British designers. Metallurgical problems solved include uranium fabrication and canning, selection of steels for pressure vessels, their erection and stress-relief. (W11, T11, 17-7; U, Mg, ST)*

Effects of Radiation on Materials, reported by Julius J. Harwood 72

Changes in metallic properties by extreme radiation by neutrons and gamma rays are explainable by displacement of atoms in the crystalline lattice or introduction of new atoms (fission products or transformed elements). (P general, G general, M25, 2-17)

How to Distinguish Brittle From Tough Steel, by Herman Greenberg 75

To insure freedom from brittle failure in service, steel should have a "nil-ductility transition (NDT) temperature" below its minimum working temperature. At temperatures below NDT, samples with a sharp notch break with all-cleavage fracture. (Q23r, Q26s, 1-4; ST)

Magnetic Analogy of a Dislocation, by A. G. Guy and L. G. Criswell 82

Two rows of equally spaced magnets, the upper one swung like a pendulum, form a physical model which illustrates that the force necessary to cause slip in a perfect crystal is much greater than in a crystal containing dislocations. (M26b, Q24a, 17-6)

The First Ferro-Uranium Made in America, by Clarence T. Patterson 85

Uranium oxide byproduct from radium refining was first smelted in an Acheson type of resistance furnace. Commercial alloy was later produced for toolsteel makers in a small carbon arc furnace, lined with sintered U_3O_8, by first forming a carbide from an oxide-coke mix, distilling off the carbon, and then dissolving boiler plate punchings in the molten uranium. (C21d, A2; U, AD-n)

Factors in the Selection of Corrosion Resistant Materials, by F. L. Whitney, Jr. 90

Ease of fabrication (especially field welding without damage), corrosion rate and cost are most important items, but operating factors — such as temperature, concentration, purity and velocity of corrosive fluid, erosion by sludge, concentration cells under adhering solids — are of equal influence on the overall economics. (R general; SGA-g)

Table of Contents Continued on Page 3

METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

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Aircraft Alloys for Thermal Flight up to 1200° F. 97
Predictions based on 40 years' history indicate that 1970 aircraft will require an "index" – that is, yield strength divided by density – of 800,000 at 1200° F. The job ahead of metallurgists is indicated by the fact that the best of our present "superalloys" reach only about 450,000 index. (Q27a, 2-12, T24; SGA-h)

Over-all Statement of the Problem, by Alfred H. Petersen 97
The Metallurgical Requirements, by Leo Schapiro 98
Material Processing Requirements, by F. R. Kostoch 100
Titanium Alloys, by Robert I. Jaffee 101
Steels for Aircraft, by R. B. Gunia 104
Tool and Die Steels, by George A. Roberts 106
Superalloys for Airframe Structures, by F. Sidney Badger 109

Cutting Tools Made of Ceramics, by Our Special Correspondent 111
Ceramic tool tips are usually made of cemented aluminum oxide, and are most valuable for uninterrupted finishing cuts on cast iron, and for machining hardened alloys or others unduly abrasive to carbide tools. Optimum tool geometry, developed by laboratory research, has been confirmed by production experience. (G17, T6n; SGA-j, 6-20)

Data Sheet

Heat Treatment Diagram for A.I.S.I. 4024, by D. J. Blickwede and R. C. Hess 96B
Typical quenching diagram – use explained on p. 114

Correspondence

Use of Heat Treat Diagrams, by D. J. Blickwede and R. C. Hess 114

Classification of Metallurgical Literature, by Frank T. Sisco 114

Russian Metallurgy, by N. H. Polakowski 118

Titanium Alloy Classification, by Daniel J. Maykuth and R. I. Jaffee; Author's Reply by T. W. Lippert 120

Hot Ductility Characteristics of Welded Austenitic Steel Pipe, by H. S. Blumberg; G. W. Rankin and R. M. Curran; R. D. Wylie; E. A. Fox and J. D. Conrad; Authors' Reply, by Henry M. Soldan and Charles R. Mayne 124

Digests of Important Articles

Alloy Steels and Protective Coatings for Jet Engines 158
Formability, cost and resistance to corrosion are important considerations in addition to usual mechanical properties.

Powder Metals for Reactors 158
Beryllium, uranium, thorium and zirconium are the metals considered.

High-Vacuum Melting of Metals 170

Corrosion Resistance of Sprayed Aluminum and Zinc 176

The Tempering of Plain Carbon Steels 180
A new hypothesis is suggested to offer an explanation of the tempering mechanism.

Embrittling Action of Salt Bath 184
Enrichment in nitrogen from the salt causes the embrittlement.

New Materials for Ball Bearings 188
Environment, particularly corrosion and heat, are important factors in determining choice of materials.

Effect of Service Temperature on Refractory Materials 191

Ultrasonic Welding 192

Rapid Heating of Steel Ingots for Hot Working 195
Rapid heating of high-alloy toolsteel ingots before forging has been found entirely safe in commercial practice.

Cavitation Erosion 198
A peculiar form of corrosion occurring on the water side of cylinder liners is a prevalent cause of diesel engine failure.

Industrial Uses of Titanium 202
Applications in commercial aircraft, and in chemical and process industries.

Departments

As I Was Saying, by Bill Eisenman 5
Application and Equipment–
New Products 23
New Literature 37
Personals 138
Volume Index 239
Advertisers' Index 248

Increase the availability of your automatic forging equipment ...at no extra cost!

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As I was saying...

—in the last issue of this column—it was swell to be out West, and it is grand now to have met all the fine people at the Southern Metals Conference in Jacksonville and at the New England Regional Meeting in Boston. These regional meetings gave me a chance to travel the circuit with President Clark. We stopped at Birmingham, Atlanta, Jacksonville, New York, Boston, Washington and Hartford.

In Birmingham we had an opportunity to face our godfather, Vulcan. In case you do not know, he is a 100-ton iron casting of a Roman mythological god. He was designed to represent Birmingham's mineral resources in the Louisiana Purchase Exposition in St. Louis in 1903. This statue of Vulcan is the largest cast iron figure in the world. From his feet to the top of his outstretched hand the statue is 55 ft. high. He stands atop a 124-ft. pedestal upon the crest of Red Mountain above the center of the city—a total height of 390 ft. Originally he held a sphere in his hand; now it is a neon torch and Vulcan has become a traffic cop. Nightly thousands of local and visiting motorists turn their attention briefly to the figure of the blacksmith god, for at nightfall the great torch Vulcan holds flares green or red depending upon the city's traffic record for the day—green for safety and red for a traffic fatality. We must have had a good influence on traffic because the light was green all the time we were there.

Vulcan is the Roman god of fire and patron of metallic handicrafts. He is the son of Jupiter. Juno, his mother, ashamed to own the child, dropped him from heaven. The infant god, falling into the sea, was rescued and adopted by Thetis, who kept him until he was nine years old, when he was restored to his parents. Soon after his return to Olympus, Vulcan took his mother's part in a quarrel. Jupiter, enraged at Vulcan's audacity, flung him from heaven again. The youth alighted on the island of Lemnos. He fashioned Pandora and had Venus given him for a wife, by whom he was the father of Cupid. His festival is celebrated Aug. 23. So much for Vulcan.

We turned the tables on Lindberg's Phil Duffy, chairman of the Atlanta Chapter, who presented President Clark and me with $120 in confederate money. Everybody sort of smiled and thought, well, he certainly overpaid the two speakers, but the next day we went to a numismatist and he informed us that the bills were originals and consequently were worth approximately $30. So we cashed the confederate money and applied the $30 to our expense account.

At the board meeting in Los Angeles the trustees voted unanimously to hold a Southwestern Metal Congress and Exposition in Dallas May 12 to 16, 1958. This is a result of the tremendous growth in industrial activity in the metals field in the ten southwestern states, of which Dallas is the central and focal point.

Everything is shaping up well for the Second World Metallurgical Congress to be held in Chicago in conjunction with the National Metal Congress and Exposition, Nov. 2 to 8, 1957. More than 500 overseas scientists, representing 36 countries, have indicated their intention to participate. The opening session of the Second W.M.C. will be a general program under the direction of Dr. Zay Jeffries, director-general of the Congress, as he was of the first W.M.C., and will be held in the ballroom of the Sherman Hotel (headquarters of the overseas delegates) on Sunday, Nov. 3.

Nine committees have been appointed by the Special Engineering Program Committee, representing the nine divisions of the Congress, for the selection of topics, speakers and overseas conferees to participate in the panel sessions which will be held during the week of the Congress.

So we will be seeing you in Chicago. Hotel reservation blanks have been mailed to all members. If you have not received yours, write the Cleveland office. Please make your reservations now.

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
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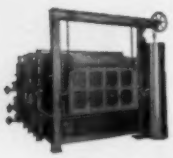
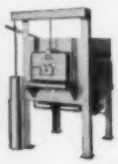
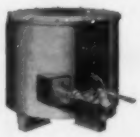


large oven



small oven

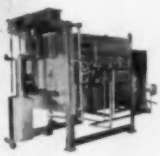
laboratory



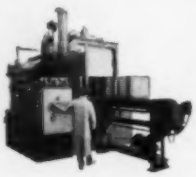
circular pot

rectangular pot

forge



balco® atmosphere



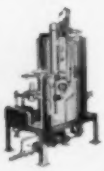
allcase® atmosphere

horizontal muffle

vertical muffle

brazing

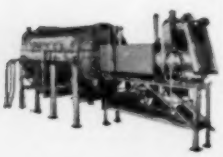
sintering



MRX® atmosphere generator

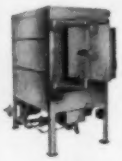
MDX® atmosphere generator

MAX® atmosphere generator



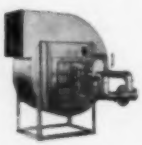
stainless steel

rivet heater



horizontal convection

vertical convection



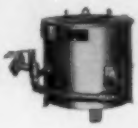
direct air heaters

C E

tilting metal melting

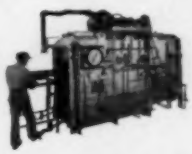
stationary metal melting

soft metal melting

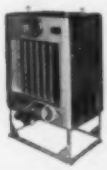


aluminum melting-holding

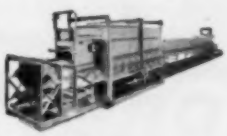
continuous snap hearth



continuous link belt



indirect air heaters



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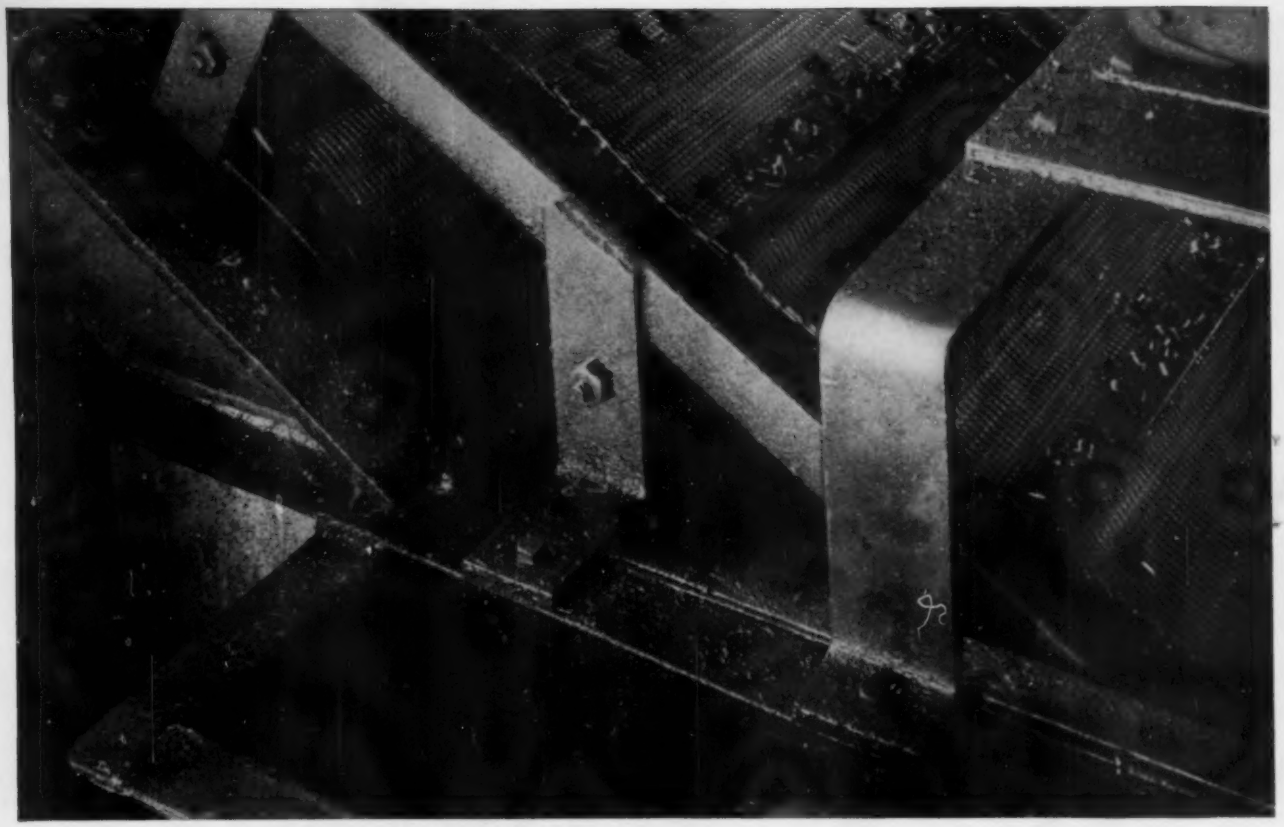

Gulf Super-Quench possesses remarkable service stability—One reason why it's the high-speed quenching oil used by Lindberg for the past ten years.

Batch elevator type atmosphere furnace used by Lindberg for clean neutral hardening, gas carburizing and carbo-nitriding. Super-Quench is a "must" on low carbon stampings and screw machine parts.

why GULF fast quenching oil

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Here Super-Quench effectively hardens pieces of low hardenability steel with a minimum of distortion.
Tom Corcoran, Lindberg Plant Superintendent, and V. O. Chase, Gulf Sales Engineer, inspect extension sockets coming out of Super-Quench, after going through a continuous atmosphere controlled furnace.

SUPER-QUENCH is the used by Lindberg Steel Treating Company

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Super-Quench offers you higher initial quenching speed than conventional quenching oils. It achieves deeper, more uniform hardening of many types of steel and produces less distortion in pieces of varied sections and shapes.

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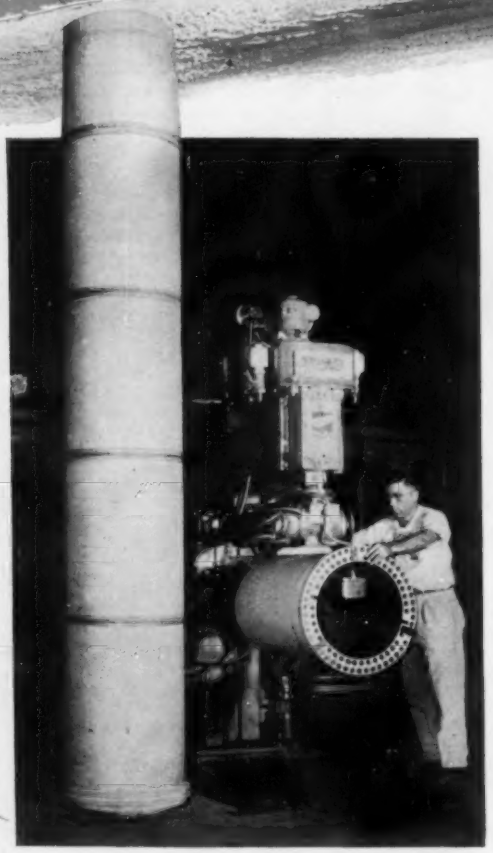
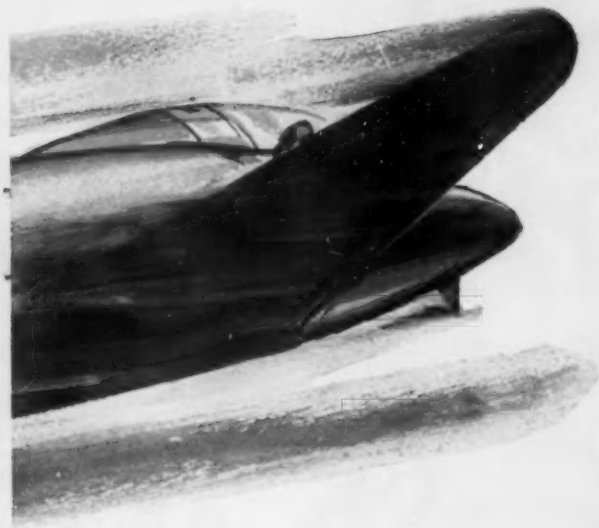


HEAT

2,000 degree jet blast!

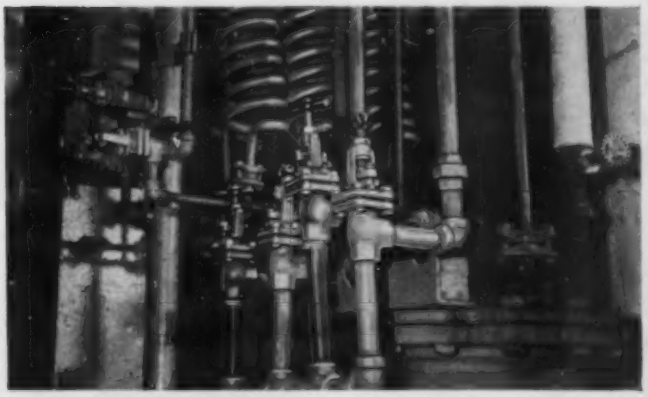
The jet engine tailpipe of the Navy's A4D "Skyhawk" operates at extremely high temperatures. That is just one of the many reasons why this part is made of MULTIMET alloy. This is one of 6 HAYNES wrought alloys that have unusual resistance to high temperatures and oxidation. Because of their exceptional properties, HAYNES alloys are being used extensively in such parts as after-burner components, jet engine tailpipes, turbine blades, and nozzle vanes.

tough problems



PRODUCTION Intricate turbine wheels mass-produced.

HAYNES' investment-casting method offers a selection of alloys developed for economical operation over a wide temperature range. Blades and wheels are produced as one integral part to as-cast tolerances that permit operation with unusually fine clearances at high speeds.



CORROSION Withstands corrosive chlorine 10 years!

Handling highly corrosive liquid chlorine was an expensive maintenance problem—until valves made of HASTELLOY alloy C were installed. This is just one of the many corrosive difficulties met by HAYNES Alloys. They also have excellent resistance to hot mineral acids, strongly oxidizing salts, and powerful gaseous oxidants over a wide range of temperatures and concentrations.

If you have an application that is creating a tough heat, wear, or corrosion-resistance problem, you will find it profitable to check with HAYNES Stellite Company. In practically every industry, you will find HAYNES Alloys doing a better job, lasting longer, reducing maintenance and proving most economical.

Tell us your problem and we will send you descriptive literature on the HAYNES Alloy best suited to solve it. Write HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, General Offices and Works, Kokomo, Indiana.

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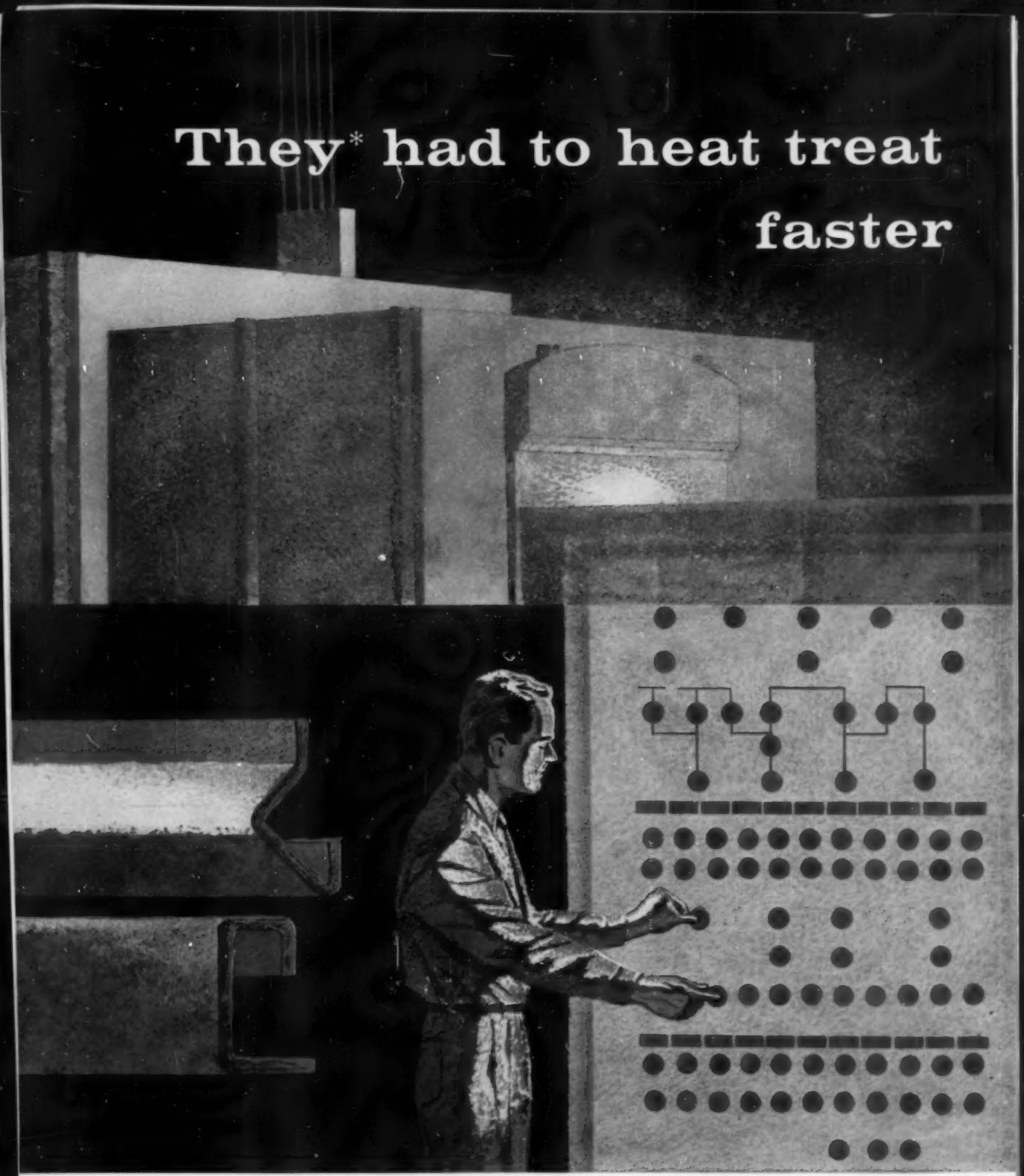
"Haynes," "Multimet," "Hastelloy" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

They* had to heat treat faster



***RESULTS: A better way to anneal extrusions** In a major aluminum plant, it used to take 3 men 8 hours to load and anneal 3600 lbs. of extrusions in a conventional, vertical furnace.

Today a Westinghouse horizontal, roller-hearth furnace and work handling system automatically handle and anneal the same charge in two-thirds the time with only two operators. Westinghouse engineered all equipment to coordinate with increased production. From a single operator station, heat and quench cycle variables are quickly programed for every batch of extrusion shapes.

...do you?

Furnace maintenance and work handling costs can eat up the profit from increased production. Over 40% of the furnaces in operation today are obsolete . . . at least 60% are twenty years old. When you have to heat-treat faster, it makes sense to specify Westinghouse equipment, developed to keep production profitable.

Westinghouse engineering puts complete equipment answers in your hands . . .

Our engineers design complete heat-treating systems using gas or electric furnaces or induction heating. From a single source you get the latest equipment answers to coordinate work handling, complete control, atmosphere preparation, furnace design and construction, quenching arrangements and safety precautions.

. . . with these flexible, timesaving steps

1. Start by calling in your local Westinghouse industrial heating representative. His analysis and on-the-spot suggestions develop your objectives.

2. Engineering and metallurgical specialists bring together equipment designed to meet your objectives.

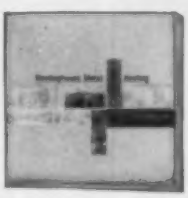
3. Westinghouse Metallurgical Research Department and Metals Pilot Plant may be called on for process improvements or test runs under simulated conditions.

4. Westinghouse complete responsibility for your heat-treating system does not end until operation checks out your personnel in actual use.

This is another example of the way Westinghouse helps you POWER-UP . . . to get better production and profit from your electrical dollar. Call in your Westinghouse representative today, or write Westinghouse Industrial Heating Division, Meadville, Pa.

J-10461

NEW . . . Westinghouse 20-page book, *Metals Heating—Gas, Electric, and Induction*. Write for your copy to Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pa.



YOU CAN BE SURE... IF IT'S

Westinghouse

Extend Metal Life Under Fire

600%

WITH HIGH VACUUM

Today, vacuum melted metals are being used by leading manufacturers of aircraft engines, turbine blades, electronic tubes, ball bearings, nuclear reactors, or wherever superior performance under high temperatures is required. For instance, use of vacuum melted alloys increased ball bearing life under high temperatures by 600%.

Limitation on product performance caused by failure of critically stressed parts can be a thing of the past. Vacuum melting produces cleaner, more homogeneous metals, which have greater fatigue life, strength, ductility, and machinability. In addition to a better product, this can often mean fewer rejects and lower costs.

If you are responsible for quality control or product performance, it will pay you to contact NRC for information on what vacuum metallurgy can do for you. Benefit from our 17 years' experience gained through building and operating more vacuum furnaces than any other organization in the world. We can help you with your program of product improvement. Write today to NRC Equipment Corp., Dept. 1F, Charlemont Street, Newton 61, Massachusetts.

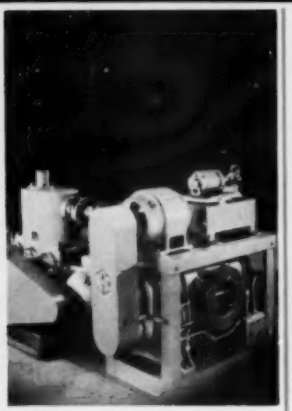
Reliable equipment for all your high vacuum needs

Cut pumping costs with less maintenance and greater dependability. Stainless body and non-corrosive parts facilitate cleaning and prevent corrosion. Complete size range from 1" to 16"

Write for bulletin No. DP-3.

Rugged new vacuum gauge with high accuracy over unusually wide range of 0.0001 — 1000 mm Hg. Thermocouple, Pirani, and hot wire ionization gauges available.

Write for bulletin No. G-3.

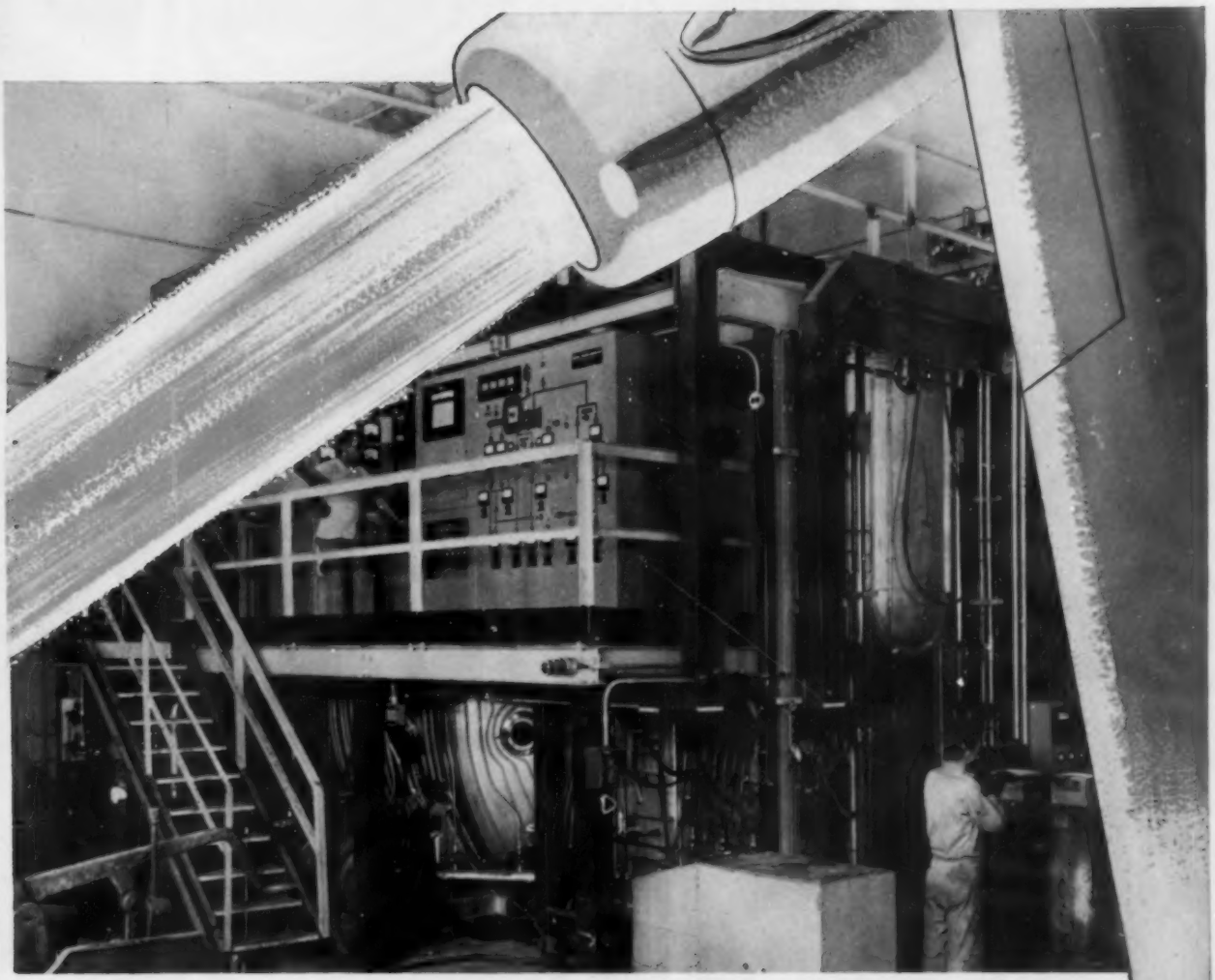


High speed vacuum pumping throughout entire micron range with NRC mechanical booster pumps. Especially suited for vacuum metallurgy. Capacities available from 1000 to 12,000 CFM.

Write for bulletin No. MB-1.

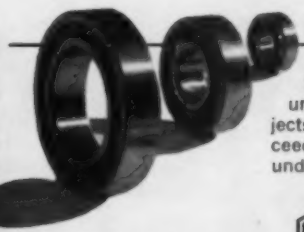
Gas content of metals determined quickly and accurately with NRC gas analyzers. Measure content of hydrogen, oxygen and nitrogen as low as 1 part per million.

Write for bulletin No. VA-2.



Gas-free, super clean, superior ingots up to 3000 lbs. are produced in this NRC Vacuum Induction Furnace. The world's largest, this unit is installed at Vacuum Metals Corporation Division, Crucible Steel Company.

Get started easily with a research, developmental or production unit. You can choose from a standard arc, resistance or induction heating furnace with capacities from 2 lbs. to 5,000 lbs.



Increased bearing life by 600% under high temperatures. Race rejects cut 90%. Handbook ratings exceeded up to 200% for bearing life under normal temperature.

NRC

NRC

EQUIPMENT CORPORATION

DEPT. 1F, CHARLEMONT ST., NEWTON 61, MASS.

A Subsidiary of National Research Corporation

Largest bronze centrifugal casting ever made, 54¾" O.D. x 49½" I.D. x 346½" long. Charge weight—72,300 pounds.

At Sandusky,

GIANTS ARE ROUTINE...

Small wonder. We serve giant industries . . . paper-making, shipbuilding, metalworking, atomic energy, petro-chemical, and others . . . with centrifugally cast cylinders and tubular parts, many of which can't be made by any other process to the exacting standards required.

It's the 47 years of specialized experience coupled with unequalled manufacturing facilities . . . that makes it routine for our engineers and production teams to cast and machine *cylinders from 7" to 54" O.D. and up to 33 feet in length* . . . in a wide range of alloys meeting special performance requirements.

Do you need a giant cylindrical form . . . or a small one . . . machined to exact working dimensions? Send us your specifications; we'll reply promptly.

Sandusky Centrifugal Castings offer you 4 important advantages:

1. ***SUPERIOR MECHANICAL PROPERTIES*** —to meet exacting design requirements
2. ***UNIFORM SOUNDNESS***—free from harmful inclusions and porosity
3. ***HIGHEST QUALITY***—to insure long, dependable, trouble-free service
4. ***JOB-READY CASTINGS***—machined to your exact specifications, eliminate extra costs from rejects, down-time, loss of production

CENTRIFUGAL CASTINGS

Sandusky Foundry & Machine Company

SANDUSKY, OHIO • *Stainless, Carbon, Low Alloy Steels—Full Range Copper-Base, Nickel-Base Alloys*

USS "T-1" STEEL WILL SAVE $800,000 IN FIRST MAJOR BRIDGE APPLICATION

Next year the State of California will open a new toll bridge paralleling an existing structure across the Carquinez Straits. This will be the final step in a mammoth project underway to relocate some twelve and a half miles of very busy highway connecting the San Francisco Bay Area with the Sacramento Valley.

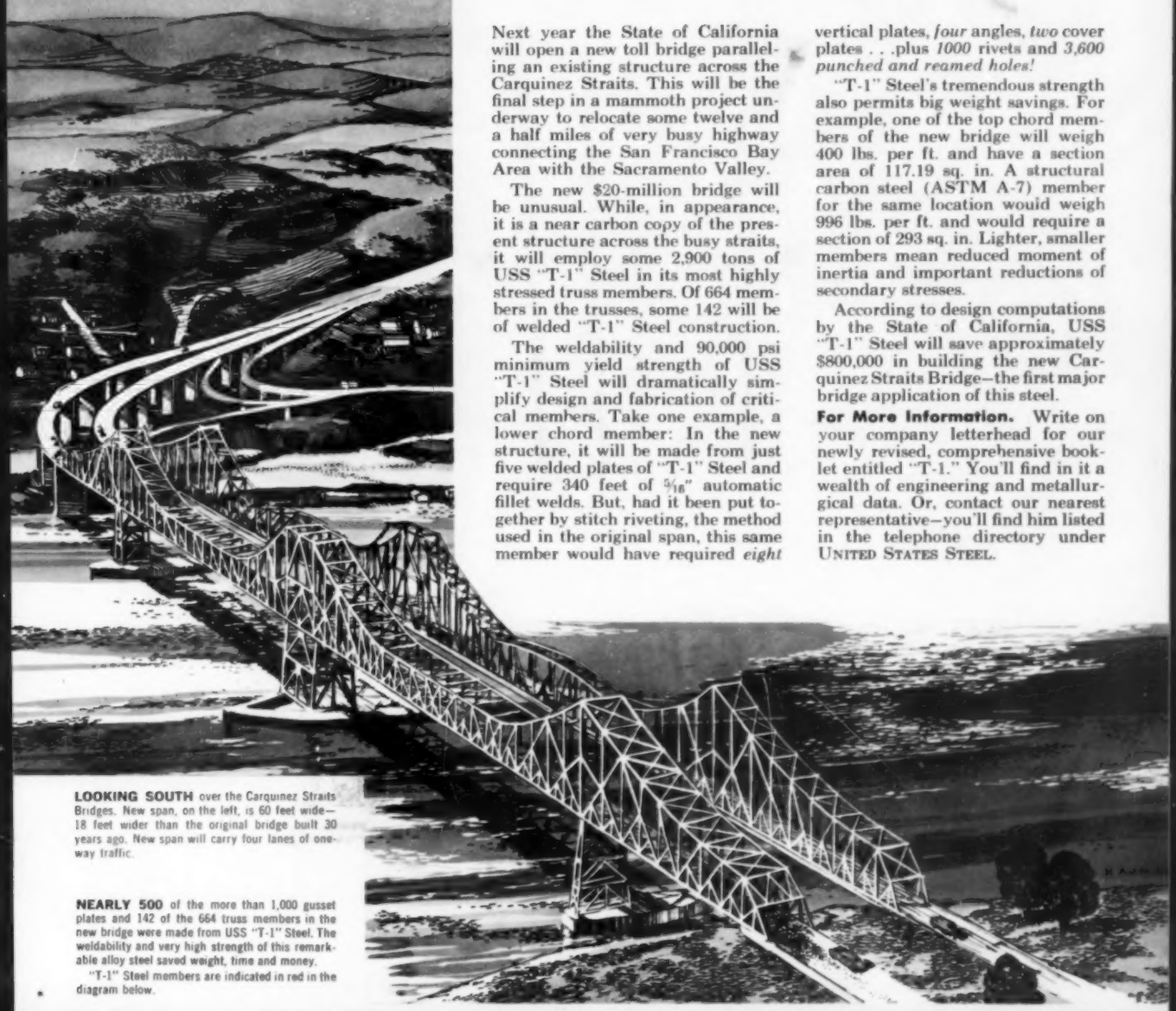
The new $20-million bridge will be unusual. While, in appearance, it is a near carbon copy of the present structure across the busy straits, it will employ some 2,900 tons of USS "T-1" Steel in its most highly stressed truss members. Of 664 members in the trusses, some 142 will be of welded "T-1" Steel construction.

The weldability and 90,000 psi minimum yield strength of USS "T-1" Steel will dramatically simplify design and fabrication of critical members. Take one example, a lower chord member: In the new structure, it will be made from just five welded plates of "T-1" Steel and require 340 feet of $\frac{5}{16}$" automatic fillet welds. But, had it been put together by stitch riveting, the method used in the original span, this same member would have required *eight* vertical plates, *four* angles, *two* cover plates . . .plus *1000* rivets and *3,600 punched and reamed holes!*

"T-1" Steel's tremendous strength also permits big weight savings. For example, one of the top chord members of the new bridge will weigh 400 lbs. per ft. and have a section area of 117.19 sq. in. A structural carbon steel (ASTM A-7) member for the same location would weigh 996 lbs. per ft. and would require a section of 293 sq. in. Lighter, smaller members mean reduced moment of inertia and important reductions of secondary stresses.

According to design computations by the State of California, USS "T-1" Steel will save approximately $800,000 in building the new Carquinez Straits Bridge—the first major bridge application of this steel.

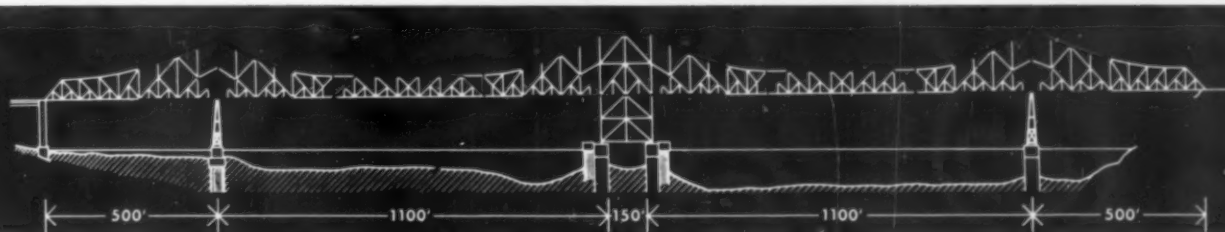
For More Information. Write on your company letterhead for our newly revised, comprehensive booklet entitled "T-1." You'll find in it a wealth of engineering and metallurgical data. Or, contact our nearest representative—you'll find him listed in the telephone directory under UNITED STATES STEEL.



LOOKING SOUTH over the Carquinez Straits Bridges. New span, on the left, is 60 feet wide—18 feet wider than the original bridge built 30 years ago. New span will carry four lanes of one-way traffic.

NEARLY 500 of the more than 1,000 gusset plates and 142 of the 664 truss members in the new bridge were made from USS "T-1" Steel. The weldability and very high strength of this remarkable alloy steel saved weight, time and money.

"T-1" Steel members are indicated in red in the diagram below.



UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST • UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

"USS" and "T-1" are registered trademarks.

UNITED STATES STEEL

"A good inspector must have

says **Thomas A. Pugh**
USS General Supervisor, Inspection

ANY MANUFACTURER worth his salt will admit that a tight inspection system is based on "the critical eyes" of his inspectors. This is especially true when you're dealing with unusual forgings that are worth many thousands of dollars.

Forgings like the nuclear reactor disc in the picture are particularly susceptible to trouble. It was forged from a chromium-nickel stainless steel ingot—a critical operation, since stainless has a very narrow temperature range in which it can be forged. To control this, a metallurgical observer stayed with the piece *every minute* it was being forged and took frequent temperature readings.

After the delicate heat-treating process, physical test bars were drilled out of the piece with a trepanning tool and subjected to accurate tensile and grain size tests. For hours, an inspector checked its soundness with a sonic crystal. Finally, we were sure that the piece was worthy to be called a USS Quality Forging.

Depending on the application and the specifications, some USS Quality Forgings require a great many more inspection steps which are sometimes spread over many weeks of shop processing. There are eleven forgings inspectors, reporting to three foremen, and they all work under the careful eye of Thomas Pugh. That's his picture on the left.

UNITED STATES STEEL

a critical eye,"

Mr. Pugh is in his 32nd year with United States Steel. He spent 30 of them as an inspector—the last 16 exclusively on forgings. Few men *anywhere* have his deep knowledge of inspection techniques and equipment, and how to use them to check large section forgings designed for critical, high-stress applications. Our faith in him is obvious: he has the authority to reject any USS Forging that does not meet our standards of quality.

In every step of the manufacturing operation—from melt shop to shipping floor—men like Thomas Pugh keep close watch over your USS Quality Forging, and they have the equipment to back them up. We'd appreciate your inquiries or requests for our free 32-page booklet on USS Quality Forgings. Just write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

USS QUALITY FORGINGS

heavy machinery parts . . carbon, alloy, stainless

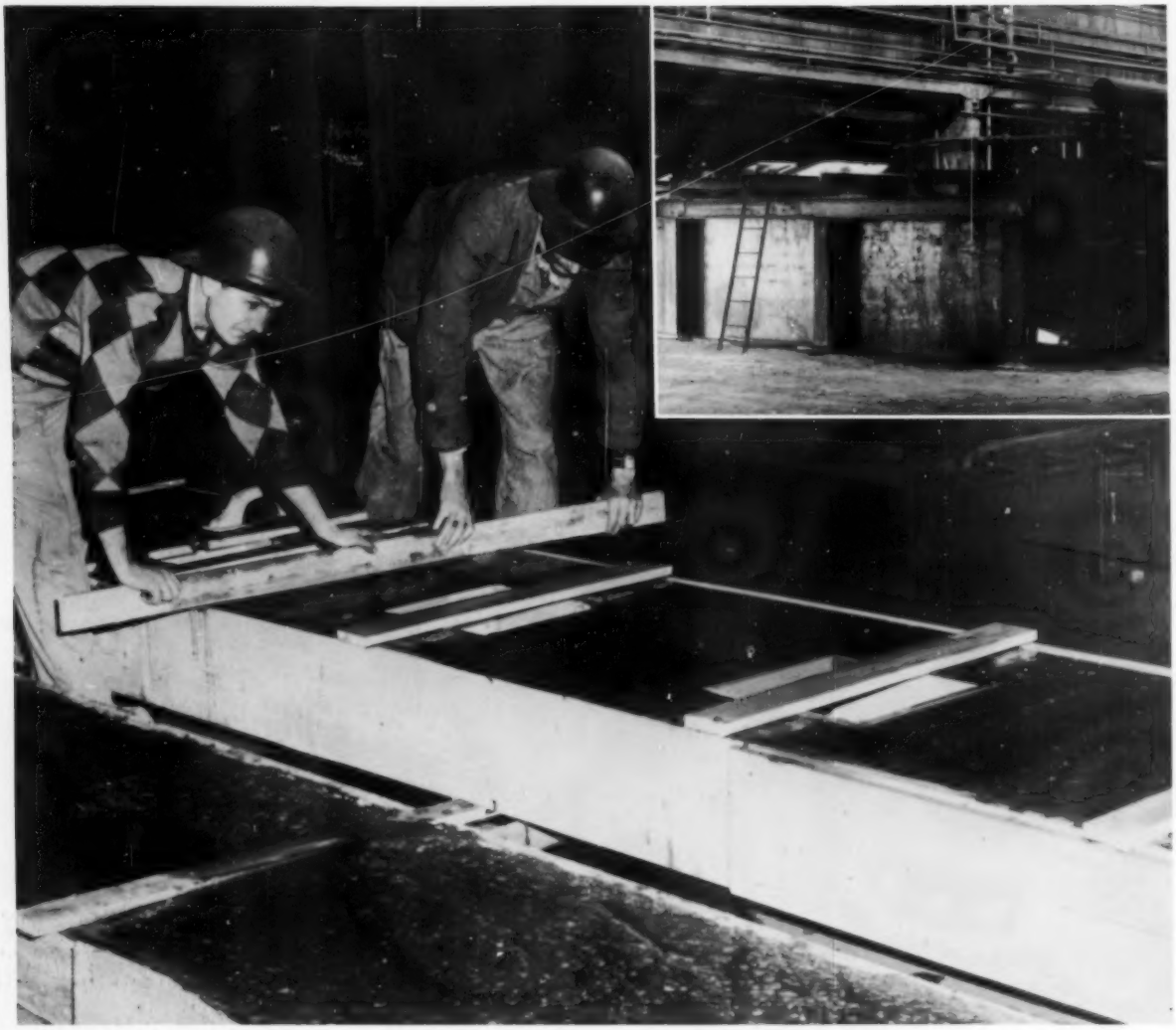
forged steel rolls and back-up roll sleeves

electrical and water wheel shafts

specialty forgings of all types

USS

UNITED STATES STEEL



REHEAT FURNACE at United States Steel plant, Duquesne, Pa., was made entirely with precast Lumnite refractory concrete panels using tilt-up construction. The 20'x40' installation was built with 18 precast sections: 4 panels each in the 2 side walls; one panel each in front and back walls; and 8 panels in the roof.

New way to build industrial furnaces—precast refractory concrete slabs of Atlas LUMNITE*

- Resists extreme variations in temperature and thermal shock due to rapid heating and cooling.
- Durability under severe operating conditions.
- Placement of Lumnite-made refractory concrete is fast and easy—service strength is reached within 24 hours.

For maximum convenience, use Lumnite-made castables. These are pre-mixed, ready for use, and are made and distributed by leading manufacturers of refractories. For more information write: Universal Atlas, 100 Park Avenue, New York 17, N. Y.

* **"LUMNITE"** is the registered trademark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

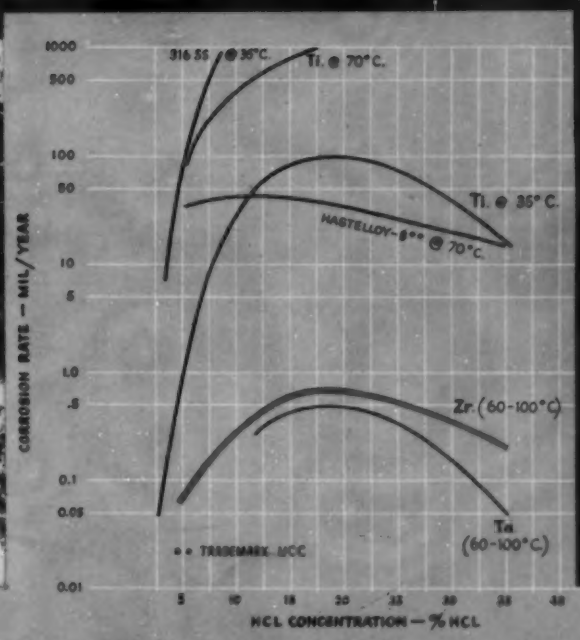
L-148

UNIVERSAL ATLAS CEMENTS

USS

UNIVERSAL ATLAS CEMENT COMPANY—member of the industrial family that serves the nation—**UNITED STATES STEEL**

OFFICES: *Albany · Birmingham · Boston · Chicago · Dayton · Kansas City · Milwaukee · Minneapolis · New York · Philadelphia · Pittsburgh · St. Louis · Waco*



want to keep a "hot fluid" in its place?

C-N ZIRCONIUM

Now, you can look at your product or process with zirconium in mind! For example, tests indicate that only tantalum is comparable to zirconium in resisting hydrochloric acid — and zirconium is less costly.

C-N Zirconium will be available in commercial quantities in the near future. Now is the time to investigate the remarkable corrosion resistance of zirconium—as demonstrated in the nuclear field and in certain industrial applications.

Columbia-National is undertaking a product research program to investigate the merits of zirconium in specific media. If you have severe corrosion problems, C-N offers laboratory and research facilities to establish how and where zirconium can solve your problem. Write us about your requirements. Send for technical data on properties and corrosion resistance of this new metal.

NEW METALS FOR INDUSTRY

Columbia-National Corporation

Jointly owned by
Columbia-Southern Chemical Corporation and
National Research Corporation
70 Memorial Drive, Cambridge, Mass.

*TRADE-MARK COLUMBIA-NATIONAL CORPORATION

CG-1

This Recuperative Atmosphere Rotary Scale-Free Heating Furnace, manufactured by The Lithium Company, Newark, N. J., employs Norton segmented conduits — *engineered and prescribed* CRYSTOLON tongue and groove tiles. Other Norton refractory shapes in the furnace are ALUNDUM burner blocks — equally efficient in aiding Lithium's recognized advancement in many heating operations.

Lithium Company reports advantages of Norton refractories

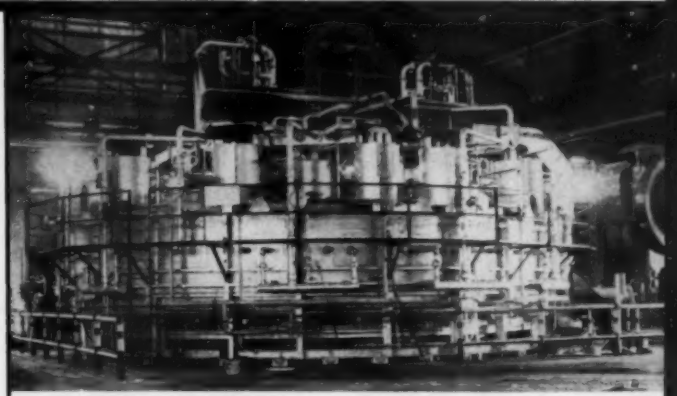
CRYSTOLON and ALUNDUM* shapes provide long, trouble-free service*

Selected by The Lithium Company for hot strength, high refractoriness, thermal conductivity and low thermal expansion, segmented conduits made of Norton CRYSTOLON tile give long, trouble-free service at temperatures up to 2900°F. ALUNDUM burner blocks have the same useful qualities, plus resistance to chemical attacks at temperatures up to 3450°F.

To Improve Your Own Furnace Performance

See your Norton Representative or *write for descriptive literature* to NORTON COMPANY, Refractories Division, 325 New Bond Street, Worcester 6, Mass.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries



One of a group of Recuperative Rotary Forging Furnaces installed by Lithium Company in a leading automotive plant for the production of *scale-free heated* billets to temperatures of 2400°F.

NORTON

REFRACTORIES

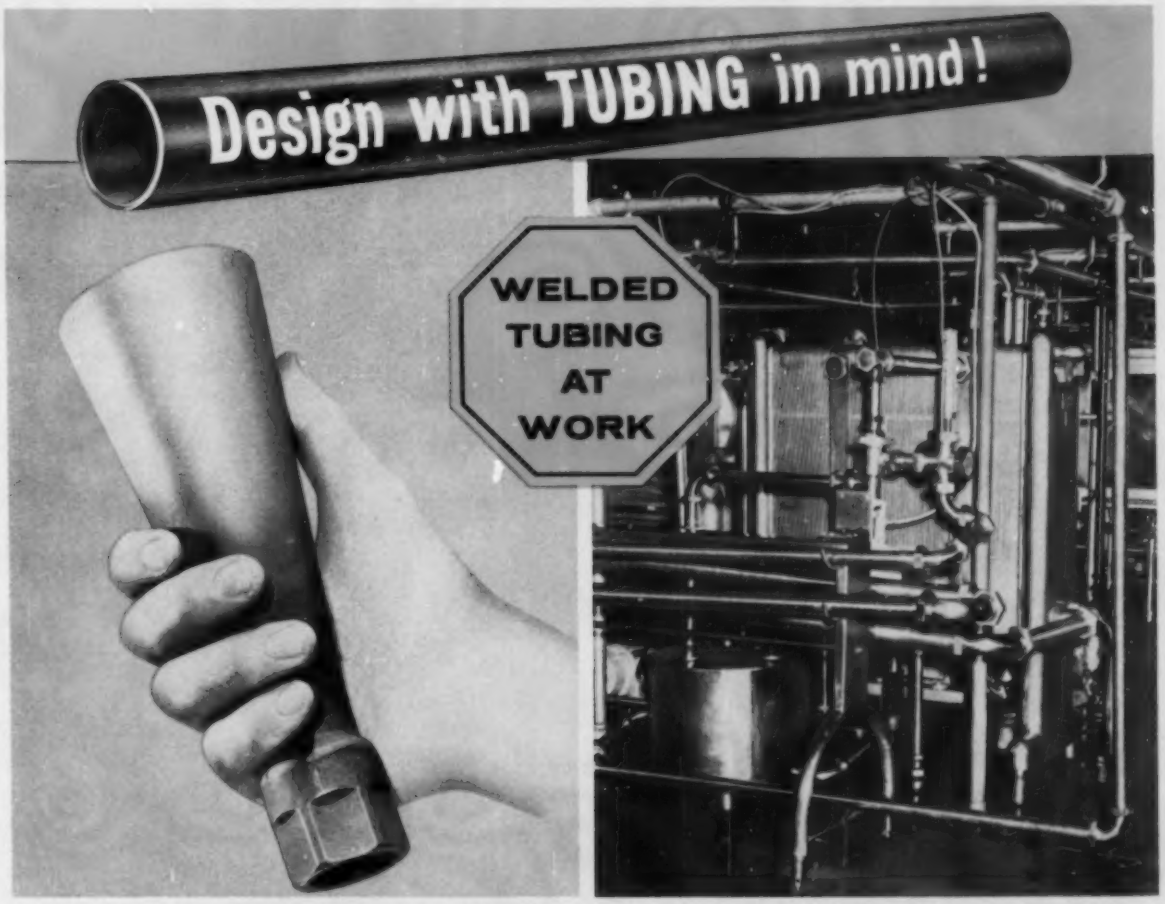
Engineered... Rx ...Prescribed

Making better products . . . to make your products better

NORTON PRODUCTS:
Abrasives • Grinding Wheels • Grinding Machines • Refractories

BEHR-MANNING DIVISION:
Coated Abrasives • Sharpening Stones • Behr-cat Tapes

Design with TUBING in mind!



Once machined from solid bar stock, this machine gun flash hider was produced at a 92% saving in cost by forming from Welded Carbon Steel Tubing.

Positive sanitation, non-contaminating, non-corrosive, non-breakable —all these call for Welded Stainless Steel Tubing in hundreds of Pasteurizers like these and all sanitary services.

Reduce fabricating costs—Insure purity

CHOOSE WELDED STEEL TUBING

Carbon · Alloy · Stainless Steel

Easy workability, outstanding uniformity, wide range of grades make Welded Tubing applicable to nearly every use requiring a hollow part. Whether a mechanical component, a structural use, to convey liquids or gases, or move at high RPM—there is a grade, size and shape of Welded Tubing that will do your job best. For all tubing applications, consult a quality tube producer.

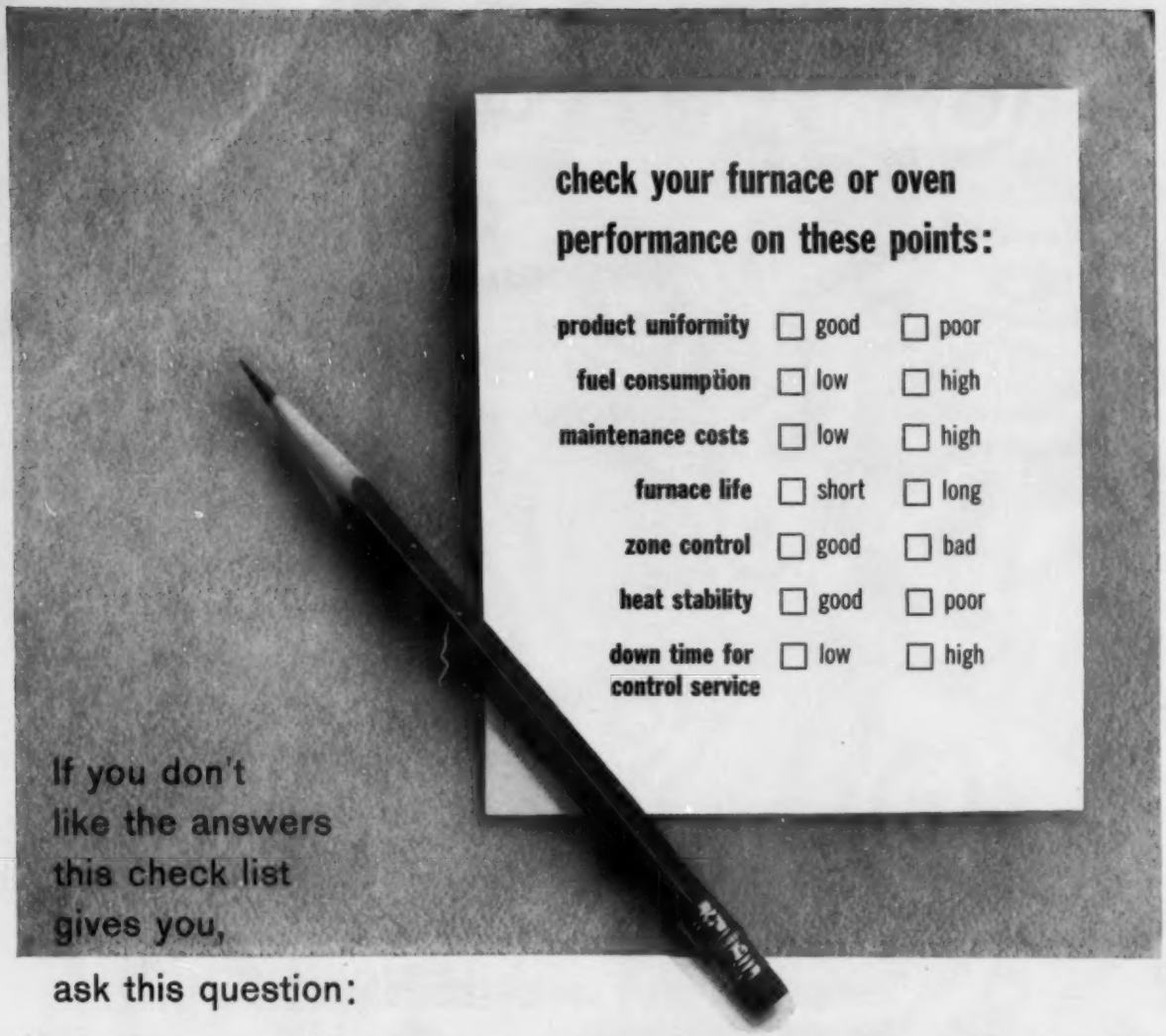
An Association of Quality Tube Producers

FORMED STEEL TUBE INSTITUTE FSTI

Design inspiration for you

The 260-page Handbook of Welded Steel Tubing contains inspiration and data for tubing designs. For your copy, write on your company letterhead, giving your title.

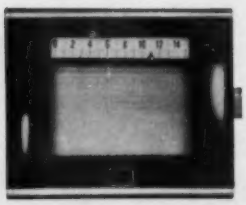
FORMED STEEL TUBE INSTITUTE
850 HANNA BUILDING • CLEVELAND, OHIO


check your furnace or oven
performance on these points:
product uniformity ☐ good ☐ poor
fuel consumption ☐ low ☐ high
maintenance costs ☐ low ☐ high
furnace life ☐ short ☐ long
zone control ☐ good ☐ bad
heat stability ☐ good ☐ poor
down time for control service ☐ low ☐ high
If you don't like the answers this check list gives you,

ask this question:

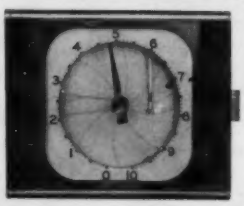
"Are my furnace controls obsolete?"

Strip-chart model



BRISTOL DYNAMASTER* ELECTRONIC PYROMETER CONTROLLERS

Round-chart model



Outmoded instruments can cost you money, lower product quality, and cut output of any furnace or oven.

New Bristol ideas are revolutionizing many older concepts of automatic control. *Bristol's great strides in electronic potentiometer development have made obsolete many instruments only a few years old.*

New product developments and production methods are placing new and unusual demands on furnace instruments and controls today.

That's why it pays to find out about the latest Bristol engineering developments before you buy another instrument or control. Take Continuous Standardization, for example—a feature you'll want on *your* next pyrometer controller. This exclusive Bristol feature, found only on Dynamaster* Pyrometers, eliminates dry cells but retains the accuracy-insuring standard cell. There's no interruption to control for standardization; no batteries to replace.

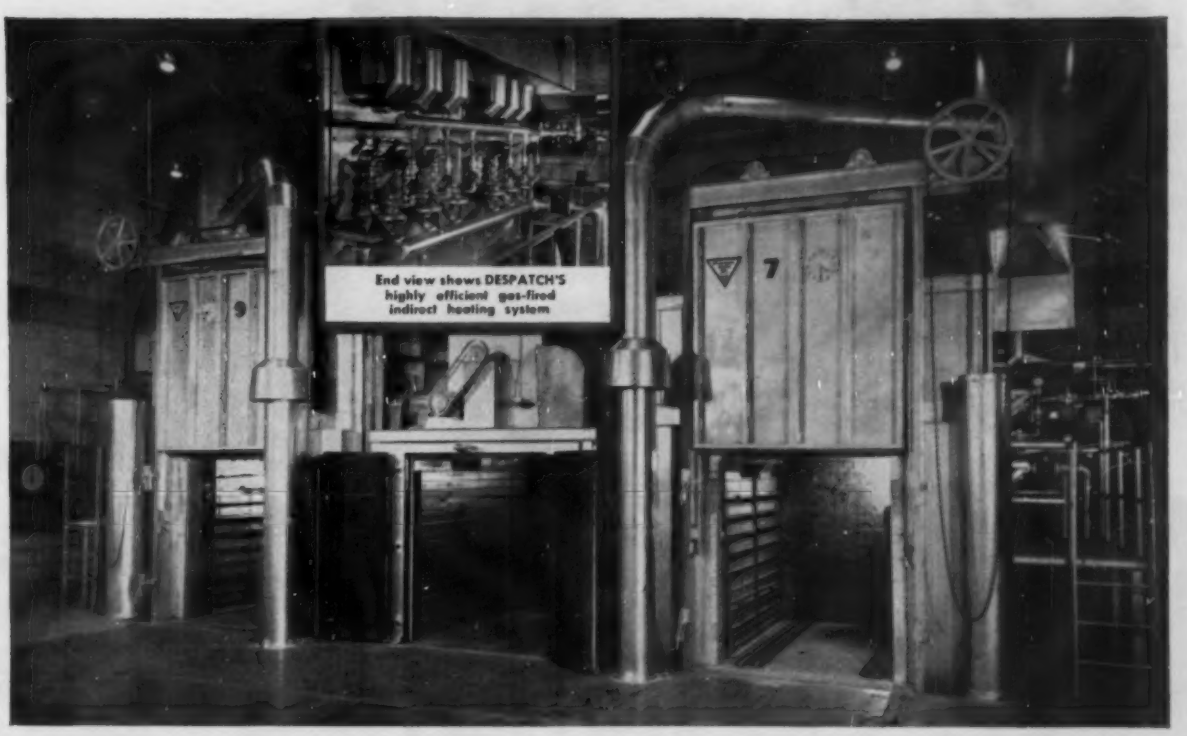
Continuous Standardization is just *one* recent Bristol development in the field of pyrometry and temperature control. To find out more, write: The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.

7.16

*T. M. Reg. U. S. Pat. Off.

BRISTOL *TRAIL-BLAZERS IN PROCESS AUTOMATION*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



For solution heat treating of ALUMINUM *industry demands fast, uniform* FURNACES *engineered for top production by* DESPATCH

When uniformity counts most . . . within ±2° . . . on load after load after load . . . that's when manufacturers such as R. C. Hitchcock & Sons call on DESPATCH for furnaces with the uniformity, economy and flexibility needed to meet the exacting requirements of today's aluminum alloy heat treating.

Shown above is the latest addition to the firm's heat treating facilities. This installation, at the Hitchcock Plant No. 2 in Bloomington, Minn., boosts their total to nine such furnaces by DESPATCH. The equipment is fully automatic; operating at 1000° F., ±2° on a 12-hour cycle with no manual assistance necessary.

DESPATCH's wealth of experience assures you the highest standard of performance. There's a DESPATCH-trained resident engineer near you. Why not talk to him about your furnace requirements?

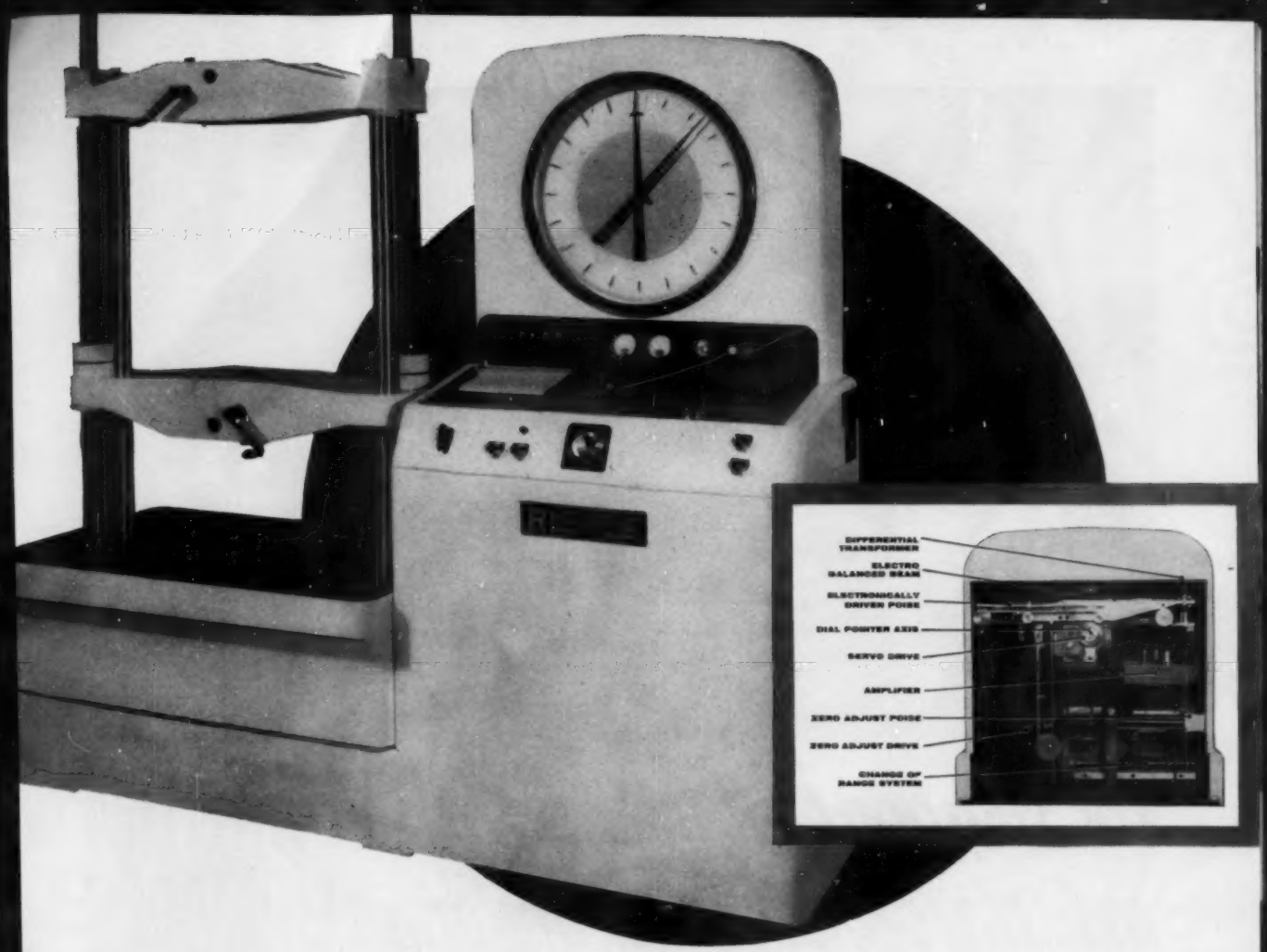
Write for Bulletin 81P

DESPATCH OVEN COMPANY

619 Eighth St. S. E.
Minneapolis 14, Minn.

Sales and Service in
All 26 Principal Cities

PIONEERS IN ENGINEERING HEAT APPLICATIONS FOR INDUSTRY



New indicating unit makes older machines obsolete

. . . it's electro balanced

At last, here is the weighing system you need for today's more rigid testing. It's more sensitive — and offers quicker response — than any other system ever built. Just a slight motion at the beam end (see rear view) provides sufficient signal to operate the servo motor . . . and move the poise to establish force equilibrium.

With Riehle's new sensitivity and rapid response plus complete instrumentation, you no longer keep confirming the "errors" that present, inadequate machines may be making. It gives you full flexibility and precision in testing at elevated temperatures as well as at room temperature. The new Electro-Balanced Indicating Unit is available for both hydraulic and screw power testing machines — by Riehle. Mail coupon for Bulletin.

Riehle TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

NEW BULLETIN . . . MAIL COUPON

RIEHLE TESTING MACHINES
Division of American Machine and Metals, Inc.
Dept. MP-657, East Moline, Illinois

Please send your free 4-page Bulletin RU-14-56 with full data on the new Riehle Electro-Balanced Indicating Unit.

COMPANY

ADDRESS

CITY ZONE STATE

ATTENTION MR.

APPLICATION and EQUIPMENT new products

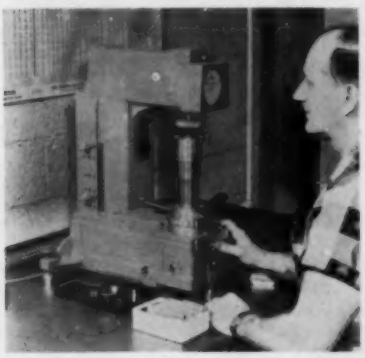
Induction Melting Furnace

Ajax Engineering Corp. has announced a 60-cycle coreless induction melting furnace in operation in its experimental foundry. It consists of a cylindrical induction coil surrounding a crucible-shaped refractory-lined hearth. Heat is induced in the metal charge. One of the outstanding features of this new furnace is the vigorous electromagnetic stirring action in the molten metal, which is particularly beneficial for fast melting of loose turnings and other finely divided scrap. Ajax-Junker furnaces are available in sizes from 1 to 10 tons, rated from 200 to 1500 kw. The 60-cycle coreless induction melting furnace was developed in Europe.

For further information circle No. 1563 on literature request card, page 48-B.

Hardness Testers

Two new Kentrall motorized hardness testers for regular and superficial tests have been announced by the Torsion Balance Co. Available as standard models in both the 8 and 12 in. vertical capacity, they reduce operator fatigue by motorization of the major load.



For further information circle No. 1564 on literature request card, page 48-B.

High-Strength Aluminum

New aluminum alloy castings for aircraft being supplied with minimum properties 50 to 100% higher than the top requirements of Federal specifications for 356-T6 alloy have been announced by American Brake Shoe Co. Ductaluminum 356S has a guaranteed minimum tensile strength of 42,000 psi. at designated high-stress areas in castings, minimum yield strength of 35,000 psi. and elongation of 3%. A second grade, Ductaluminum 356T, guarantees elongation up to 6% with a slight reduction in tensile and yield minimums. Ductaluminum 356 castings are supplied on the basis of mechanical properties of test coupons cut from the casting itself. At least one casting in each lot is so tested.

For further information circle No. 1565 on literature request card, page 48-B.

Metal Identification

Procedures for a new 1-min. identification test for Monel, nickel and stainless steel types 302, 304, 316 and 317 are announced by Techalloy Co. It uses an electrographic method to determine the metal. Procedure sheet details the Moly test. Equipment needed is a 6-volt dry cell battery, aluminum strip, photographic blotting paper and spot reaction paper. Three solutions are used and their formulas are shown. Results which determine the metal tested are explained.

For further information circle No. 1566 on literature request card, page 48-B.

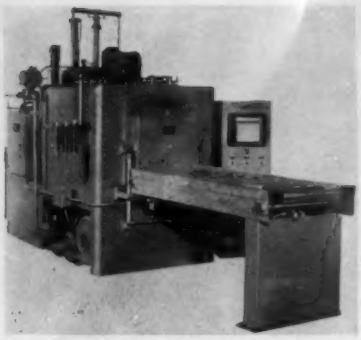
Ultrasonic Cleaner

Alcar Instruments has announced a new ultrasonic cleaner for use on production line or in laboratory. It may be used for cleaning meters, high precision parts and complex assemblies. It operates off a generator of 250 watts output or more. The tank is 7⅛ in. deep by 6½ in. in diameter. Designed for continuous operation, the cleaner is water cooled.

For further information circle No. 1567 on literature request card, page 48-B.

Heat Treating

An all-new controlled atmosphere heat treat system has been announced by Eclipse Fuel Engineering Co. A complete package installation includes matching combination heat treat furnace and quench tank, endothermic generator, tempering unit and automatic washer. Basic unit in the system is the automatic controlled atmosphere heat treat furnace with a maximum operating temperature of 1850° F. Automatic straight-through handling of work is provided with a power pusher moving the work into the heating chamber, and a separate pusher head transferring work to the rack in the quenching chamber. Quenching cycle is automatic with the rack being raised and lowered by a pneumatic cylinder. A two-stage, 300-gal.-per-



min. pump recirculates the quenching oil. A jet agitator system helps circulate the oil through densely packed loads. Work area of both the heat chamber and the quench rack is 24 in. wide by 36 in. long by 18 in. high.

For further information circle No. 1568 on literature request card, page 48-B.

Resistance Alloys

The Kanthal Corp. has announced a new ultra high-temperature electrical heating and resistance material. The new material is structurally a cermet and is designed for continuous element temperatures up to 2900° F. Kanthal Super consists principally of $MoSi_2$ and SiO_2 and is produced by a powdered metallurgical process. It is available in various diameters and is easily formed to suit individual furnace requirements. During the first few hours in use, the material undergoes a self-sintering which increases hardness and strength and produces a durable element with excellent mechanical and electrical stability. After initial oxidation and break-in no further aging occurs so that new and old elements may be connected together without difficulty.

For further information circle No. 1569 on literature request card, page 48-B.

Finishes

Allied Research Products has announced the introduction of four new products. Iridite No. 5-P is a powdered concentrate which produces a yellow iridescent coating on zinc and cadmium plate, galvanized iron and zinc die castings. The resulting finish is corrosion resistant and also provides a base for paint. Iridite No. 8-4 is all-purpose liquid chromate for all forms of zinc and cadmium. It can be used to provide a bright finish or a highly protective coating. Iridite No. 12-P is a powdered material designed to provide a one-dip, clear, blue-bright finish on zinc-plated parts. Iridite No. 14-9 is a powdered concentrate designed to provide a one-dip, clear protective treatment for aluminum surfaces which meets the requirements of specification MIL-C-5541.

For further information circle No. 1570 on literature request card, page 48-B.

Leak Detector

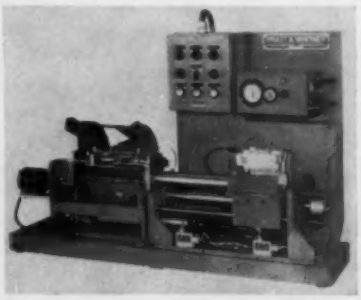
A new leak detector which detects and locates a leak so small that it will admit less than 2 cu. in. of gas per year has been announced by NRC Equipment Corp. The new halogen sensitive instrument is operated by connecting to the system or part under test which is then evacuated with a mechanical vacuum pump.

When a pressure of 80 to 200 microns is attained, the outside of the part is blanketed with Freon-12 tracer gas. If a leak is indicated, further probing with a fine stream of gas locates the leak.

For further information circle No. 1571 on literature request card, page 48-B.

Thickness Gage

A new automatic gaging machine that checks the wall and bottom thickness of tubes and automatically separates them at the rate of 1000



units per hour has been announced by the Pratt & Whitney Co. Aluminum tubes are fed into a chute from which they are transferred to a nest of rubber rolls rotating at approximately

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■ Whenever your product requires special components with superior wear qualities, precision surface finish that provides dependable long life service under severe operating conditions, specify Cleveland Hard Facing.

As specialists in the application of welded hard facing metal overlays, we are completely equipped and qualified to economically produce hard faced components to meet your specifications. For practical assistance on your application, call on one of our specialists.

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Application Specialists Of Wear, Corrosion And Heat Resistant Overlays

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600 rpm. As the tubes rotate, gaging contacts enter the open ends exploring the wall thickness on the helix that is generated. At the end of the stroke, bottom thickness is measured. After the gaging slides are retracted at faster-than gaging speed, the contacts operate two Sigmatic Microlimit gage heads which sort the tubes into classification conveyors which discharge them into bins of usable, rectifiable and rejected units.

For further information circle No. 1572 on literature request card, page 48-B.

Solution Pot

A new type solution pot with a cast bottom and wrought side has been announced by General Alloys Co. The cast bottom is uniform throughout and its high strength prevents sagging and deformation of the pot during use. Wrought side is joined to the cast bottom by inert-gas shielded welds. These pots are available in any size or shape, in any heat or corrosion resistant metal in thicknesses from 3/16 to 1 in. or more.

For further information circle No. 1573 on literature request card, page 48-B.

Welder

Miller Electric Mfg. Co. has announced two improved models of gasoline-engine driven welders. Now equipped with a new and larger Onan

12.9 hp. engine, the models produce 225 amperes of continuous rated, high cycle welding current. They are portable and the new design features shielded muffler and larger gas tank to match increased power output.

For further information circle No. 1574 on literature request card, page 48-B.

Surface Active Agents

A new series of Poly-Tergent nonionic surface active agents has been announced by the Industrial Chemicals Div. of Olin Mathieson Chemical Corp. The temperature range over which the products are effective extends from —32 to 212° F. The "J" series consists of four products of ascending molecular weights. All are aliphatic polyoxyethylene ether alcohols. Poly-Tergents J-300, J-400 and J-500 can be used in the preparation of soluble oils and metal cleaners. All are suitable for use in acid pickling.

For further information circle No. 1575 on literature request card, page 48-B.

Wire Belts

The Cambridge Wire Cloth Co. has announced the introduction of an entirely new design for pintle-type chain for belt installations where a chain drive is required to move heavy loads or to assure positive motion, such as through heat treating cycles or during inclined movement. This new type of chain was developed expressly for use on woven wire belts. The new design incorporates a heavier shoulder that provides equal bearing surfaces at both the open and closed ends of the link. Thus, distribution of bearing stresses is equalized and longer chain life may be expected. The connecting pin is free-floating, rather than fixed as in older designs, so that wear will occur around the full circumference

From first heat to heat treat . . .

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DIRECT-FIRED SINGLE-STACK

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When warranted by special conditions, radiant tube or multiple stack construction are also available.

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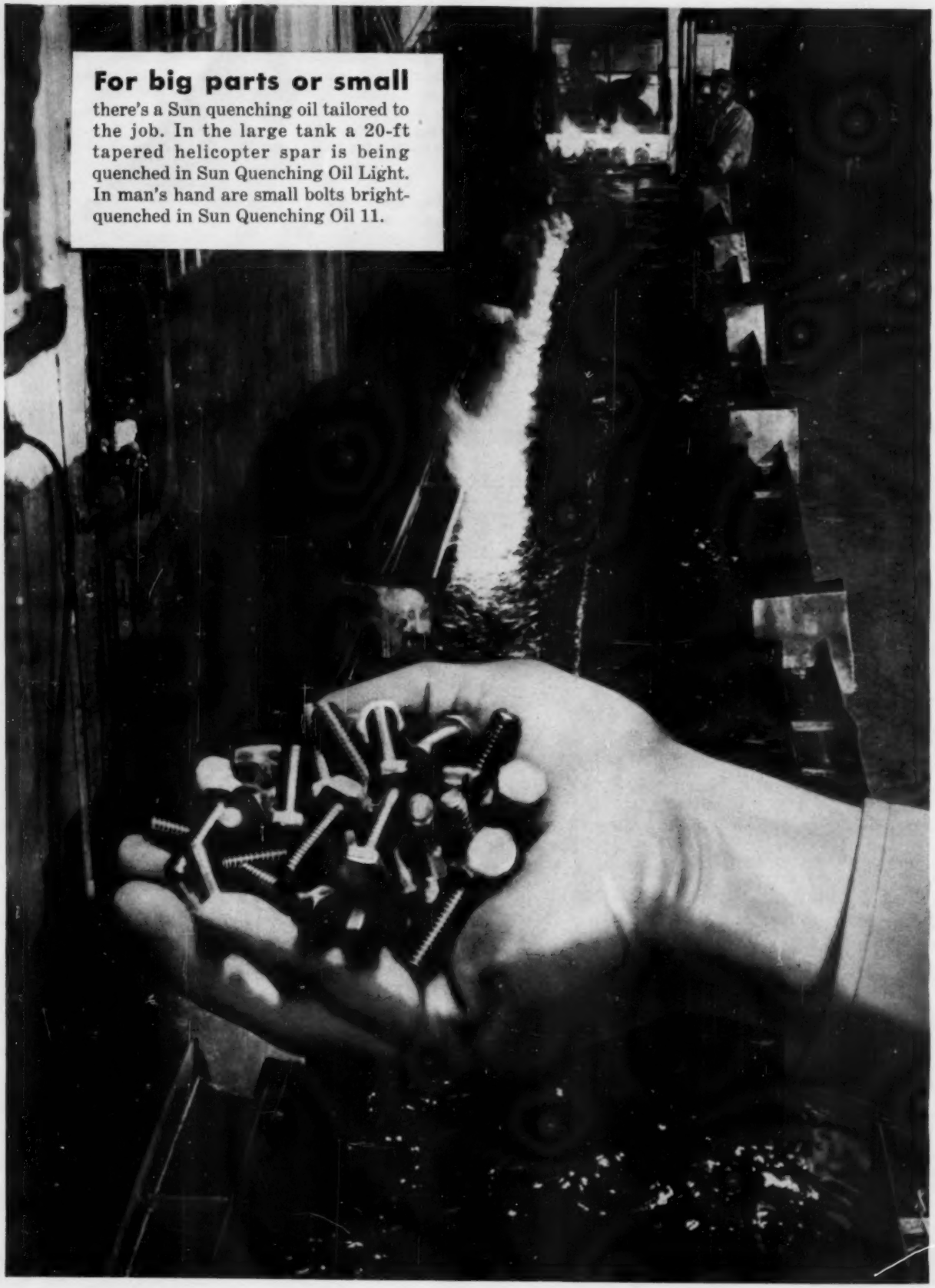

For big parts or small
there's a Sun quenching oil tailored to the job. In the large tank a 20-ft tapered helicopter spar is being quenched in Sun Quenching Oil Light. In man's hand are small bolts bright-quenched in Sun Quenching Oil 11.

SUN QUENCHING OILS CAN SOLVE ALL OF YOUR OIL-QUENCH PROBLEMS

SUN QUENCHING OIL LIGHT keeps coolers cleaner longer because it has a natural detergency that cuts down sludge formations. By using Sun Quenching Oil Light many people have cut cooler maintenance costs by as much as 75 to 80 per cent. And they're getting low drag-out and uniform quenching.

SUN QUENCHING OIL 11 has a high flash point. Moreover, it resists breakdown at high temperatures. These characteristics make it ideal for bright quenching and for use in systems operating at above-normal temperatures.

SUNQUENCH 78 is a high-speed quenching oil. You can use it whenever the nature of the steel, the size and shape of the parts, or other conditions make it difficult to get satisfactory results with conventional quenching oils. By using Sunquench 78, steels of lower hardenability may often be used to replace more expensive steels.

IN ADDITION to these three quenching oils, Sun makes several others for special applications. No matter what your quenching problem, there's a Sun quenching oil to solve it.

READ THESE TECHNICAL BULLETINS

Free technical bulletins are available to give you full details of Sun's outstanding quenching oils. Call your Sun representative or write for **Sun Quenching Oil 11 (Bulletin 29), Sun Quenching Oil Light (Bulletin 37), Sunquench 78 (Bulletin 45).**

Write to SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-6.

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INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY PHILADELPHIA 3, PA.

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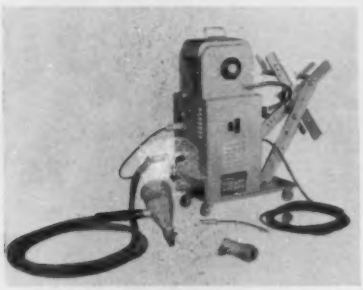
of the pin, not at localized areas. Because of the completely symmetrical design of the new link, the assembled chain will operate on standard sprockets.

For further information circle No. 1576 on literature request card, page 48-B.

Semi-Automatic Welding Unit

A new semi-automatic submerged arc welding unit has been announced by Hobart Bros. Co. The new unit is completely equipped with all controls and control power cable for plugging in on 110 volts, either d.c. or a.c., wire



reel, caster mounted base, and carrying handles. A gun cable assembly is included with two welding guns, which are interchangeable—one flux type with hopper and one open-arc type for welding without flux. This unit is designed for use with any arc welder having continuous current up to 50 amp. using solid wires 5/64 or 3/32 in. and tubular wires ?/32 or 7/64 in.

For further information circle No. 1577 on literature request card, page 48-B.

Rust Remover

A new powdered acid material which removes rust, scale and corrosion has been announced by Oakite Products, Inc. It is added to water in concentrations upwards of 8 oz. per gal. Solutions of the compound may be used cold or for faster action, heated to 165° F. A major advantage of this new material is its ease in shipment and in storage, as it requires no returnable carboys but is shipped in fiber drums. It may be used on aluminum, brass and galvanized surfaces.

For further information circle No. 1578 on literature request card, page 48-B.

Ultrasonic Degreaser

A small-scaled duplicate of large ultrasonic degreasers has been developed by the Ramco Equipment Corp. This bench model can be used in engineering institutions, colleges,

chemical testing laboratories and for continuous production work. It cleans such typical parts as ball bearings, surgical instruments, watch and instrument parts, tools and dies, hydraulic valves. The work area is 9 by 9 by 6 in. with a capacity of 100 lb. per hr. Construction is of stainless steel and it features thermostatic control, filter, manual spray, copper cooling coils, stainless heater and solvent recovery system.

For further information circle No. 1579 on literature request card, page 48-B.

Weatherproof Gages

Recording gages for pressure, vacuum and water or liquid level measurements in new weatherproof cases have been announced by the Bristol Co. They are designed for wall or pole mounting outdoors. Both 8 and 12-in. round chart models are available in the new cases; flowmeters and thermometers are also offered.

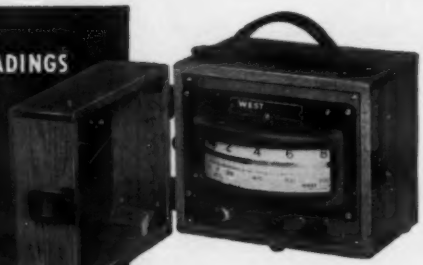
For further information circle No. 1580 on literature request card, page 48-B.

Speed Transmitter

A new pneumatic speed transmitter announced by the Foxboro Co. produces a pneumatic output linearly proportional to rotational speed. It

will measure the speed of any rotating machinery and is particularly applicable to turbines, conveyor lines, compressors and mill equipment. Transmitter range is adjustable from

ACCURATE TEMPERATURE READINGS
WHEREVER AND WHENEVER WITH *Veri-tell* PORTABLE PYROMETERS BY WEST



These rugged, handy precision-built instruments are widely used for taking spot readings where permanent installations are needless and for checking other instruments. Each mounts a Veri-Tell high resistance pyrometer in a gasketed aluminum housing, itself contained in practical Oak Case with lock and handle. Quick, positive service is assured by binding posts for attaching thermocouple. Automatic meter shunt protects meter when case is closed. Fully *guaranteed* and surprisingly *low priced*. Write for Catalog IE-1.

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Many standard and special thermocouple assemblies including hand probes are available to permit reading—

- Surface temperature of dies, etc.
- Temperature of non-ferrous molten metal
- Immersion temperature of hot oil, wax, solder pots, etc.

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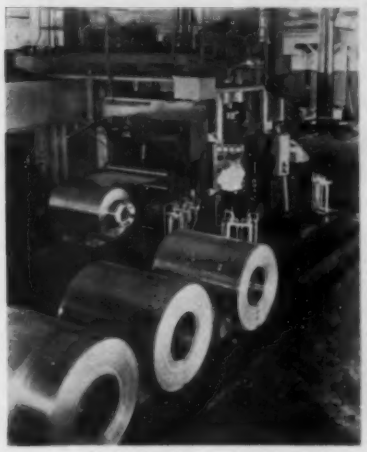
0 to 1600 rpm. up to 0 to 2400 rpm. by a fine range adjustment screw and extended to 0 to 320 rpm. through 0 to 5300 rpm. by optional speed changers. Instrument can be assembled to measure clockwise or counterclockwise rotation, or the 3 to 15 psig. output can be split to accommodate both forward and reverse rotation within the range limit.

For further information circle No. 1581 on literature request card, page 48-B.

Rolling Aluminum

A 4-high mill with 12 and 36 by 62 in. rolls, a combination slitting-shearing line and a continuous annealing furnace which double sheet and strip rolling capacity have been announced by E. W. Bliss Co. The mill can squeeze 0.125 in. aluminum strip 56 in. wide down to 0.070 in. in a single pass—a reduction of 45%. It will also

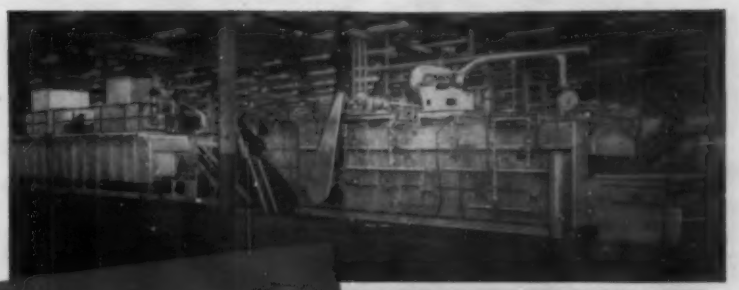


roll fine gage, down to 0.004 in. Maximum mill speed is 1500 fpm. The mill is one-way, with completely mechanized coil-handling and a powered-roller conveyor system to return coils to the entry side for further passes. The new slitting and shearing line takes up to five cuts in 0.125 in. material 46 in. wide at a speed of 200 to 600 fpm.

For further information circle No. 1582 on literature request card, page 48-B.

Descaling Stainless Steel

Development of a new process for descaling precipitation hardened 17-7 PH stainless steel after it has received the transformation hardening cycle has been announced by Turco Products. The process consists of three steps: 1) After precleaning and prior to heat treating, apply Turco pre-treatment coating to metal surfaces. This coating prevents the formation of tightly adhering oxides during heat treatment. 2) After heat treating, remove pre-treatment coating along



4000 lbs. per hour ...in Automated Harden Quench and Draw

A large automotive plant required furnaces to heat treat 4,000 lbs. per hour of forgings or castings automatically. The equipment had to be durable to produce a constant uninterrupted flow of parts and also effect a substantial saving over previous methods.

Industrial's direct fired continuous belt type hardening furnace and famous "CIRC-AIR" draw are doing the job. Loading 35 lbs. per square foot of conveyor, hardening is at 1700 deg. F., quench in 1700 gallons of oil and temper at 1200 deg. F.

The rugged, dependable Industrial furnaces are completely automatic; produce 4,000 lbs. per hour every hour every day.

Besides saving man hours, there is a 20% fuel saving by use of the continuous belt conveyor operating wholly within the hardening furnace.

Industrial's "CIRC-AIR" draw furnace is the most efficient heating machine made for temperatures up to 1300 deg. F. High velocity fans force recirculated hot gases through the work with no temperature head. Thin and thick sections come to heat evenly; and the entire load is heated uniformly.

Send for "CIRC-AIR" Bulletin No. 13-A

CIRC-AIR

INDUSTRIAL HEATING EQUIPMENT CO.

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PIONEERS AND STILL LEADERS IN RECIRCULATION

Sheffield Tube Corporation reports: *Kemp Melting Pot melts 2,200 lbs. of lead per hour, eliminates down-time*

The Sheffield Tube Corporation, New London, Conn., manufactures tubes for toothpaste, cosmetics, drug specialties and similar products. Slugs for extruding are punched from thin lead sheets, which are rolled from moulded slabs. To melt large "pigs" for moulding these slabs, Sheffield formerly used three pots: two meltdown pots, feeding into a 1,276 lb. capacity holding pot. This equipment has been replaced by one Kemp Immersion Melting Pot, capable of melting 2,200 lbs. of lead per hour.

Kemp boosts production . . . cuts down-time

Formerly, one man produced about 500 slabs daily; dross formation had to be removed two or three times daily; and the pots were replaced after anywhere from 6 weeks to 6 months of operation. With the Kemp Melting Pot, two men now mould about 1,400 slabs daily. During the first 5 weeks of service dross was not removed once—and except for an occasional 10-minute valve-cleaning job there was no down-time at all.

Kemp can help you

Whatever your application, it will pay you to investigate Kemp Melting Pots. You'll benefit in many ways: Kemp units are not subject to periodic and expensive breakdowns . . . offer greater heating surface, faster heat recovery, lower dross formation, lower room temperatures. Whatever your problem, Kemp units will help cut labor costs, eliminate lost time, increase output.

Find out how Kemp engineers can provide the most profitable solution to your heating or melting problems. Write for Bulletin IE-11, today.

KEMP OF BALTIMORE

IMMERSION MELTING POTS

CARBURETORS • BURNERS • FIRECHECKS • ATMOSPHERE & INERT GAS GENERATORS • ADSORPTIVE DRYERS SINGEING EQUIPMENT

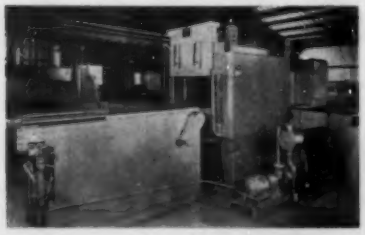
THE C. M. KEMP MFG. CO.
405 East Oliver Street, Baltimore 2, Maryland

with heat treat oxides in descaling solution. 3) Pressure rinse, to remove any residual oxides.

For further information circle No. 1583 on literature request card, page 48-B.

Automatic Furnace

A new furnace for high-production automatic heat treating has been announced by Pacific Scientific Co. Charging is accomplished by placing the work load on the automatic loader, opening the pneumatically-activated

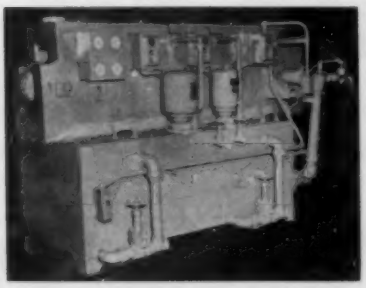


door and pushing a button on the console control. Heating elements are placed on each side of the work load (as well as under the load on electrically heated units) and a fan provides atmosphere circulation. Quenching oil is distributed through a large-diameter perforated pipe. Oil is forced down through the top of the work load by means of a high-volume, high-velocity recirculating pump. Furnaces are available in three standard sizes, providing controlled temperatures to 1850° F. and featuring load capacities from 600 to 1400 lb. at a heating rate of 400 to 1200 lb. per hour.

For further information circle No. 1584 on literature request card, page 48-B.

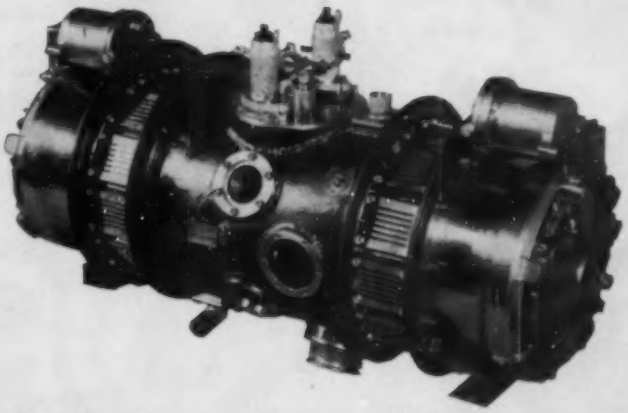
Parts Washer

A new washing machine for removing chips, filings, oil and grease from screw machine products has been announced by Industrial Systems Co. The machine employs a metal mesh



conveyor to carry the work parts through powerful sprays of heated detergent solution followed by a hot rinsing spray. The cleaned parts are then discharged from the machine ready for the next operation. The machine measures 6 by 3 by 4 ft. and processes parts up to 6 by 3 in. It is heated by gas, but may be adapted

Looking ahead with FORD and PORUS - KROME



FORD'S experimental free piston gassifier has PORUS - KROME plated cylinder bores . . . . . in engine and compressors.

TOMORROW'S automotive power may be here today in Ford's free piston gassifier.

That's Design Engineering's job . . . to look and plan ahead . . . to build Now for the future.

When Ford engineers were designing this gassifier, excessive piston speed and attendant friction dictated the selection of the most wear resistant material on the cylinder bores -- to withstand punishing abuse.

That's where Van der Horst entered the picture.

Van der Horst Corporation's extensive plating know - how, quality craftsmanship and their patented Porus - Krome process for plating porous chromium made the company first choice.

This is another example of Van der Horst's engineered plating services -- designed to solve problems involving wear, corrosion and abrasion.

What is PORUS - KROME? Porus-Krome is to chromium as stainless steel is to steel -- a processed improvement of a basic material specifically designed to meet the demands of a special application. Porus-Krome has ALL the superior physicals of chromium PLUS an affinity for lubricants.

For more detailed information on PORUS-KROME, write Van der Horst Corporation, 1666 East St., Olean, New York.

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TERRELL, TEXAS OLEAN, NEW YORK
LOS ANGELES, CALIFORNIA* CHICAGO, ILLINOIS
HILVERSUM, HOLLAND

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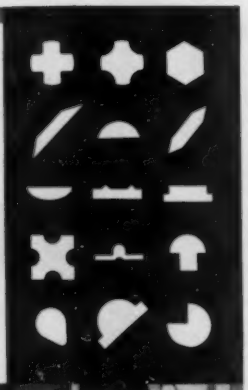
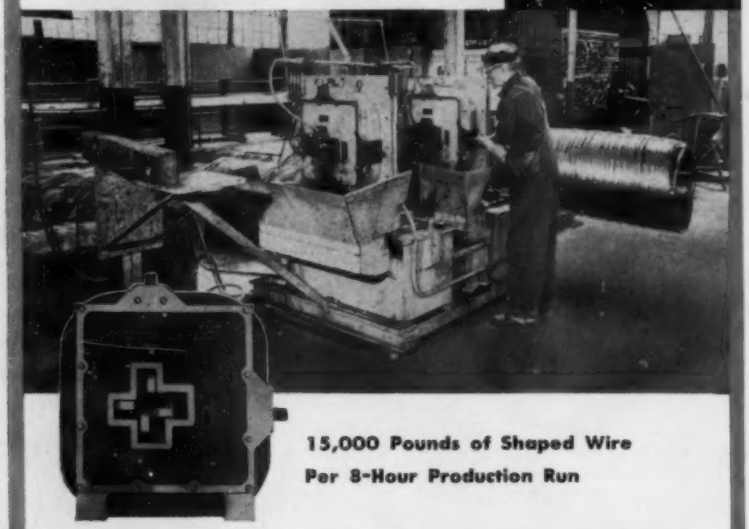
Wire Shaping

BETTER, FASTER at LOWER COST





15,000 Pounds of Shaped Wire Per 8-Hour Production Run

The Fenn 4U Universal Type Tandem Turks Head is shown in use at The National Lock Washer Company in Newark, New Jersey. Prior to being formed into lock washers and retaining rings, the wire is drawn through the tandem Turks Head for a two-step reduction which in this case results in a keystone-shaped cross section. The Shaped Wire Division of National Lock Washer, 100% equipped with Fenn Turks Heads, turns out 10,000 to 15,000 pounds of shaped wire every 8-hour production run with only three operators required to maintain this high production rate. Fenn Turks Heads may be used singly, in tandem as illustrated, or in tandem with a rolling mill or draw bench. For complete information on the capabilities, advantages and capacities of the four basic types of Fenn Turks Heads, send today for the new illustrated Turks Head Catalog No. TH56.

FROM ROUND

TO KEYSTONE

IN A SINGLE PASS

FENN Turks Heads

Fenn Manufacturing Co., 504 Fenn Road, Newington, Connecticut

for steam and electricity. The unit may be connected to turret lathes and other machining operations.

For further information circle No. 1585 on literature request card, page 48-B.

Heat Treating

A specially designed heat treating furnace which prevents erosion of aircraft parts has been announced by Surface Combustion Corp. A load of jet engine compressor blade rings is shown being unloaded from this

pit-type draw furnace. The construction of the basket facilitates discharging of the rings by use of an overhead hoist. One complete charge weighs about 940 lb. Tempering is carried out between 1100 and 1200° F. using cycles from 2 to 6 hr.

For further information circle No. 1586 on literature request card, page 48-B.

Immersion Thermocouple

A new thermocouple for high temperature molten metal measurements up to 3100° F. has been announced by the Bristol Co. This thermocouple uses a metal-ceramic secondary protecting tube, a vitrified alumina primary tube, and a platinum-platinum-

10% rhodium thermocouple. A curved stainless steel tube of any required length leads to a wooden grip and thermocouple assembly head. The standard model will have 8 ft. of armored connecting wire. Life tests indicate that the secondary tube will normally withstand about 10 dips in molten steel between 2700 and 3100°

Automobile trim of

Superior Stainless STRIP STEEL

You can't tell the age of a car by its stainless steel! After a thousand or *two hundred thousand miles* of driving, Superior Stainless gleams good as new. • Enjoy the beauty of stainless on the cars *you* buy —costs you nothing in care, gives you everything in pride and pleasure!

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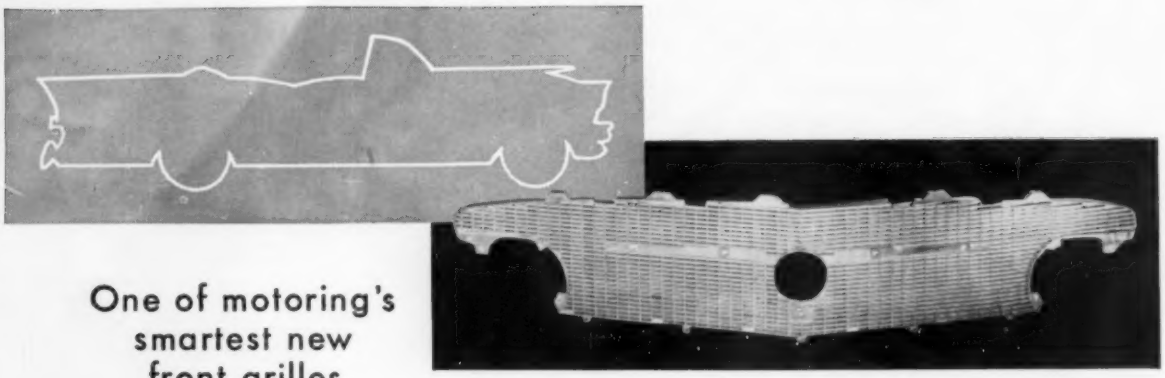
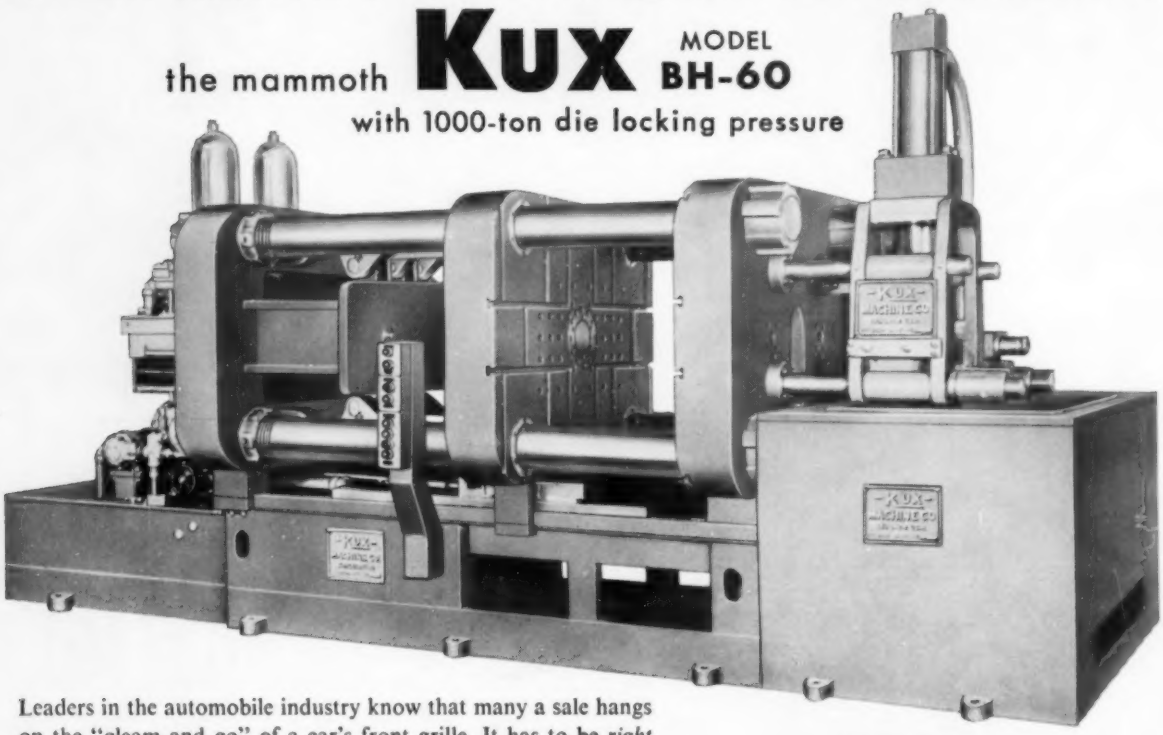


One of motoring's smartest new front grilles

cast on America's outstanding die casting machines

the mammoth **KUX** MODEL **BH-60**

with 1000-ton die locking pressure



Leaders in the automobile industry know that many a sale hangs on the "gleam and go" of a car's front grille. It has to be *right* for looks, for strength, for serviceability. And equally important, it must be engineered to allow for speed of production.

That's why the industry's top designers depend upon Kux quality die casting equipment to turn out the handsome new front grille illustrated above.

The grille weighing 24 lbs. in zinc, cast in one piece, measures 59″ x 12″ and is produced at an average speed of 80 per hour. The die, in which this part is made, is 70″ x 50″, and requires tremendous pressure to keep it locked under the force of the metal being injected. Therefore, the BH-60 machine having 1000 tons die locking capacity is utilized for this all powerful job.

Through the years, innumerable other leading manufacturers and die casters have profited from their acquaintance with the advanced die casting machines perfected by KUX. Why shouldn't you?

MODEL BH-60

Kux Hydraulically Operated Plunger Gooseneck Die Casting Machine for the Production of Lead, Tin or Zinc Castings

Also Available as HP-60, a Cold Chamber Model for the Production of Aluminum, Brass or Magnesium Castings

KUX

MACHINE COMPANY

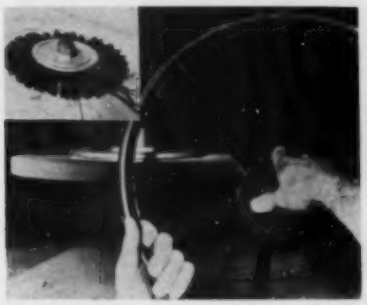
6725 North Ridge Avenue, Chicago 26, Ill.

Builders of a full range of die casting machines... from 25 tons to 1000 tons in size.

F. Lower temperatures will give proportionally longer life.
For further information circle No. 1587 on literature request card, page 48-B.

Polishing

A design change in the Vonnegut brush back polishing head has been announced by the Grinding & Polishing Machinery Corp. Heads are built



in 1-in. widths and are furnished with long-trim bristle brushes when specified. They are useful for contour surfaces or on intricate designs.
For further information circle No. 1588 on literature request card, page 48-B.

Induction Heating

A two-station work table designed to perform hardening, brazing, annealing and soft soldering operations has

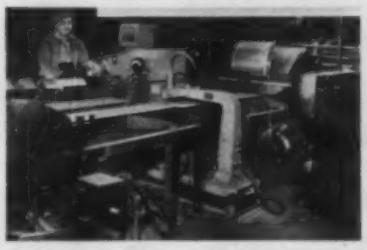
been introduced by Welduction Corp. Standard units are equipped with 220/440 3-phase motor generators in ratings from 7½ to 30 kw. The work table has an output of 220 volts, 10 kc., single phase. Unit comes fully equipped for immediate installation.
For further information circle No. 1589 on literature request card, page 48-B.

Hard Facing

A new line of hard surfacing electrodes with low hydrogen coatings has been announced by Metal & Thermit Corp. The new line includes 14 different types of electrodes, each designed to combat a specific type of wear. With less moisture in the coating, weld metal porosity is reduced and there is less cracking. Extensive field testing also reveals that penetration into the base metal and dilution by the base metal is at a minimum and greater resistance to impact, abrasion and corrosion are obtained.
For further information circle No. 1590 on literature request card, page 48-B.

Thickness Inspection

Automatic inspection of tin plate sheets for thickness at the rate of 60 to 100 sheets per minute at the plant of Youngstown Sheet and Tube in East Chicago has been announced by Industrial Gauges Corp. An Xact-Ray thickness gage scans each sheet and makes possible the withdrawal of the individual sheet found to be off tolerance. The installation is working



on sheets with a minimum length of 16 in. and a maximum of 45 in. and thickness of 0.006 to 0.019 in.
For further information circle No. 1591 on literature request card, page 48-B.

Pangborn Hydro-Finish cut cleaning time 50% in this plant

Paid for itself in only six months

Pangborn Hydro-Finish really paid off for this leading glass manufacturer. Cleaning quality increased moldlife 10% to 15% and total cleaning and polishing time was cut in half! The resultant savings paid for the machine in six months and represented a substantial weekly sum thereafter.

Today, through new design and use of air jet sluriators, Pangborn Hydro-Finish costs less originally, costs less to maintain and gives you easier handling and added efficiency. Write for Bulletin 1403 to PANGBORN CORP., 1800 Pangborn Blvd., Hagerstown, Md.

USE PANGBORN HYDRO-FINISH FOR:

Deburring • Surface finishing • Finishing threaded sections • Improving cutting tool life • Maintaining dies and molds • Removing grinding lines • Removing heat treat scale • Preparing surfaces

Pangborn

BLAST CLEANS CHEAPER

SODIUM
hydride descaling

tough cleaning job?

Have you irregular castings, pipes, bars, sheets, wire, molds that need cleaning or descaling? If that's your problem, try sodium hydride. This fast, money-saving method descales a wide range of metals and alloys. And does it in only minutes!

Equipment is compact, low in cost, easily maintained. No problems of waste disposal, pitting or loss of metal. Base metal is never attacked . . . sodium hydride acts uniformly on high spots and crevices alike.

Like to test this modern, highly efficient descaling method? The coupon below will bring descriptive literature. Or, if you prefer, one of our experienced Chemical Engineers will be glad to call and discuss your needs. Just mark your choice.

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NORRISTOWN, PA.

All analyses .010 to ¼ in. OD—certain analyses in light walls up to 2½ in. OD

what's the latest news in induction heating?

Cincinnati's new Inductron® induction heating machine is *new all the way through!* It offers more advantages in performance, flexibility, ease of operation, control and maintenance than any similar equipment previously available to industry for rapid selective surface hardening, annealing and brazing work.

The new Inductron is available in 15, 30 and 50KW capacities . . . each is housed in one complete, compact, self-contained cabinet of the *same* size. The units are wired and equipped to operate on either voltage, 220/440. The machine operates at high frequency (450,000 to 1,000,000 c.p.s.) which makes possible rapid heating, confined to the skin surface for minimum depth of case, narrow transition zone, freedom from scale and minimum distortion.

Many more design advantages—in circuitry and component construction; in controls and instruments—are incorporated. For the complete story on the brand new Inductron, write for your copy of Bulletin No. M-1993. Better still, call in a Process Machinery Division field engineer. Let him brief you on the many Inductron advantages.

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flamatic and inductron

hardening machines

THE PROCESS MACHINERY DIVISION

THE CINCINNATI MILLING MACHINE CO.

CINCINNATI 9, OHIO, U. S. A.

APPLICATION and EQUIPMENT new literature

1593. Abrasion Tester
Bulletin 5409 on new model standard abrasion testing set describes machine and its operation. *Taber Instrument Corp.*

1594. Abrasive
New bulletin on aluminum oxide abrasive grain. Advantages. Toolroom grinding wheels using this abrasive. *Simonds Abrasive Co.*

1595. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it may be used with and parts that may be cleaned. *Globe Steel Abrasive*

1596. Abrasive Cleaning
Catalog 54-W on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass, Brush Div.*

1597. Abrasives
18-page catalog 556 on various types of shot and grit abrasives. SAE specifications and types of cleaning and peening methods. *Cleveland Metal Abrasive*

1598. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

1599. Alloy Castings
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

1600. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

1601. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

1602. Alloy Steel
Comparative tables of SAE and AISI standard steels and tentative standard steels. *Babcock & Wilcox*

1603. Aluminum Bronze
20-page booklet on chemistry, physical properties and uses of aluminum bronze alloys in rolled, extruded and cast forms. *Ampco*

1604. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1605. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions, Inc.*

1606. Arc Welding
8-page reprint on recent developments in inert-arc welding. Applications, equipment, fixtures. *Linde Air Products Co.*

1607. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

1608. Atmosphere Furnaces
New 4-page bulletin on single and double recuperative atmosphere furnace for forging and rolling. *Furnace Div., Lithium Co.*

1609. Atmospheres
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

1610. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal," contains uses, formulas, calculations. *W. M. Chace*

1611. Black Oxide Coating
7-page bulletin gives recommended procedures for black oxide finishing of ferrous alloys. Data and rules to insure uniform results and eliminate difficulties. *Swift Industrial Chemical*

1612. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

1613. Blast Cleaning
8-page bulletin 1403 on liquid blast cleaning equipment. Drawings of cabinets. *Pangborn Corp.*

1614. Blast Cleaning
Bulletin No. 703 gives complete specifications and dimension of Blastmaster barrels from 1.5 cu.ft. to 27 cu.ft. Automatic operations. *Pangborn Corp.*

1615. Blowers
Specifications and instructions 300 on turbo blowers describe installation, maintenance, assembly. *North American Mfg.*

1616. Bolts
16-page booklet on high-strength bolting for structural joints includes ASTM specifications covering this bolting material. *Bethlehem Steel*

1617. Brazing
4-page reprint on use of salt baths in production and small scale brazing of simple and complex assemblies. *Ajax Electric*

1618. Brazing
New 4-page catalog on high-temperature brazing alloys. Characteristics and physical properties. *Wall Colmonoy Corp.*

1619. Burners
8-page Bulletin SC-1004 on ribbon burner describes burners, heating techniques and gives selection data. *Selas*

1620. Burners
32-page catalog on industrial gas burners and gas furnaces for heat treating carbon and alloy steels. Pot furnaces and melting furnaces. *Charles A. Hones*

1621. Calibrating Machine
Bulletin 115 on calibrating system for accurate measurement of mechanical forces. *Morehouse Machine*

1622. Carbon Control
12-page catalog TD4-620 (2) on Microcarb atmosphere control for carbon potential in Homocarb furnaces. *Leeds & Northrup*

1623. Carbon Control
16-page bulletin on equipment for carbon and sulphur determination, including combustion furnaces and other accessories. *Harry W. Dietert*

1624. Carbonitriding
28-page booklet on nature of process, furnaces, atmospheres, parts carbonitrided and properties. *Armour Ammonia*

1625. Case Hardening
Handbook on Nitrocycle case hardening and how it reduces finishing costs. *Oil Well Supply Div., U.S. Steel*

1626. Castings
8-page brochure on design characteristics and mass-production advantages of die castings. Die making and permanent mold castings. *Harvill Corp.*

1592. Zirconium and Hafnium

This new 12-page booklet describes the uses of zirconium and hafnium, their mechanical and physical properties and the sodium process for producing the metals. It includes tables

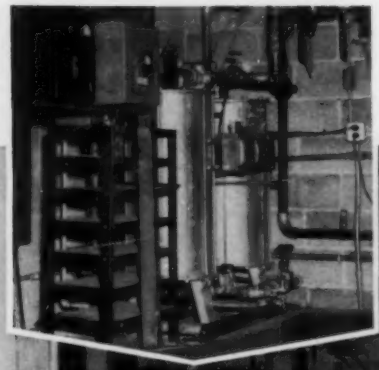
describing zirconium's resistance to 21 chemical reagents and compares it to the resistance of four other metals. Four pages are devoted to the zirconium binary alloy systems. *U.S. Industrial Chemicals Co.*

1627. Centrifugal Castings
8-page brochure gives properties of most common grades of thermalloy centrifugally cast tube. Weight tables. *Electro-Alloys Div.*

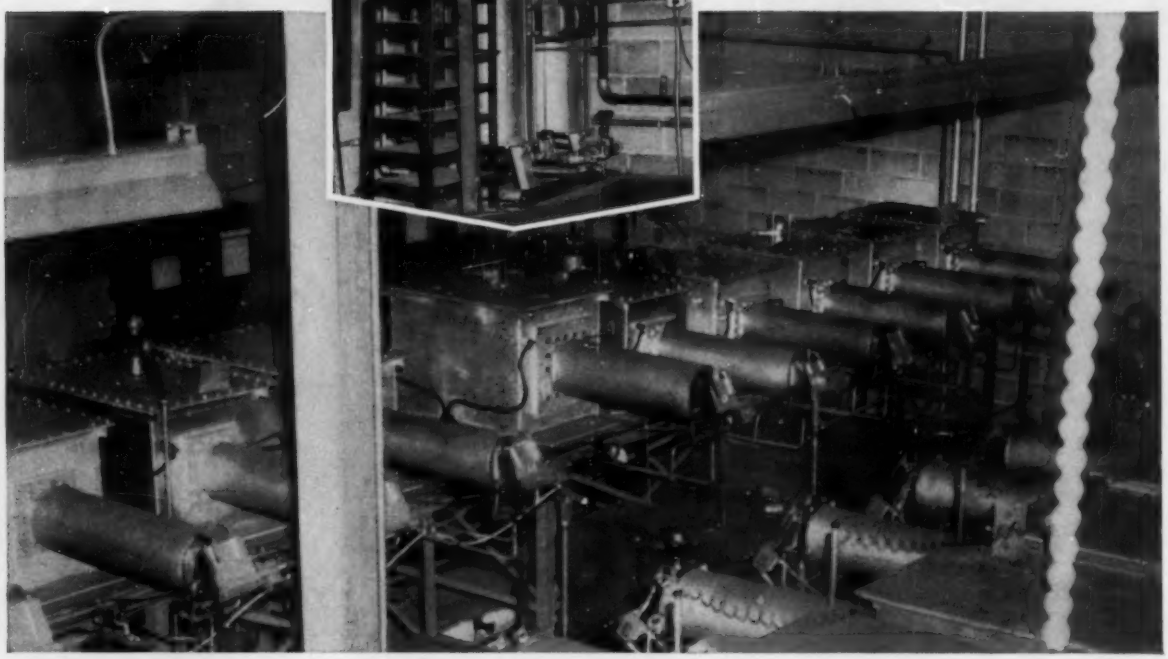
1628. Centrifugal Castings
Folder on which centrifugal castings are available. Compositions, properties, standard designations. *Sandusky Foundry and Machine Co.*

1629 Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1630. Chromium Treatment
4-page bulletin on atom exchange process for creating a chromium-rich surface on ferrous metals. *Alloy Surfaces Co.*



This Lectrodryer processes the hydrogen fed to all the Adamas sintering furnaces (a few are shown below). After leaving the Lectrodryer, the hydrogen atmosphere registers a dewpoint below –100° F.



Adamas Carbide insists on DRY hydrogen for sintering

Hydrogen dried to a dewpoint below –100°F prevents surface oxidizing of carbides being sintered at Adamas Carbide Corporation's ultramodern plant at Kenilworth, New Jersey.

To obtain such dryness, Adamas follows two steps:

(1) The hydrogen feeds through a catalytic cylinder which converts every trace of free oxygen into moisture.

(2) Then the hydrogen passes through a Lectrodryer* which snatches moisture from the gas, delivering it at a dewpoint somewhere below –100° F.

You can obtain similar dryness

Lectrodryers will economically remove unwanted moisture from air or other gases in a continuous, automatic cycle. For large or small volume—low or high pressures (to 6000 psi)—Lectrodryers of all types and sizes are available to solve your problem.

Talk it over with a Lectrodryer engineer. The booklet, *Because Moisture Isn't Pink*, describes how industry is using Lectrodryers. For a copy, write Pittsburgh Lectrodryer Division, McGraw-Edison Company, 317 32nd Street, Pittsburgh 30, Pennsylvania.

In France: Stein et Roubaix, 24 Rue Erlanger, Paris XVI.
In Belgium: S. A. Belge Stein et Roubaix, 320 Rue du Moulin, Bressoux-Liege.

Lectrodryer

*REGISTERED TRADEMARK U. S. PAT. OFF.

1631. Chromizing Process
8-page bulletin on corrosion resistance of chromallized iron and steel. *Chromalloy*

1632. Cleaning
Folder on di-phase cleaning gives equipment, construction features, spray and blow-off features, heating systems. *Solventol*

1633. Cleaning
48-page pocketbook on how to clean aluminum and magnesium. Steps involved, methods, equipment. *Oakite*

1634. Cleaning
New 8-page booklet on wetting agents, detergents, emulsifiers. *E. F. Houghton*

1635. Cleaning Aluminum
12-page bulletin on cleaning process for preparing aluminum and magnesium for welding. *Northwest Chemical*

1636. Cleaning Compound
Bulletin B-6 on water displacing compound for producing unspotted, dry surfaces. *Apothecaries Hall*

1637. Coated Metals
New bulletin on roll coating shows how it is done and includes samples. *Roll Coater, Inc.*

1638. Cold Rolled Steels
32-page booklet on stainless, alloy and carbon spring steels, and other specialties. Melting, temper, finishes. *Crucible Steel*

1639. Contour Machines
16-page bulletin on equipment for contour sawing, filing, polishing operations. *DoAll Co.*

1640. Controls
56-page catalog 857 on automatic controls for heating and industrial applications—pressure, temperature, liquid level, etc. *Mercoid Corp.*

1641. Controls
12-page booklet on pneumatic controllers. Standard and optional features. Diagram shows how the system works. *Leeds & Northrup*

1642. Copper Alloys
60-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupronickel. Chemical and physical data. Engineering tables. *Riverside Metal*

1643. Copper Alloys
48-page book contains tables of alloys with composition, typical uses, general, working, mechanical, electrical properties, hardness, ASTM specification numbers. *Revere*

1644. Core Binders
Bulletin 450 on line of binders for oil-sand cores, air-setting cores, CO_2 gassed cores and resin bonded cores. *Foundry Div., Archer-Daniels-Midland Co.*

1645. Cutting Stainless
8-page bulletin on shearing, blanking, perforating, friction sawing and flame cutting of stainless. *Crucible Steel*

1646. Cutting Tools
New 12-page catalog on high-strength oxide base cutting tools. Properties, tool holders, dimensions and prices of throw-away inserts, solid inserts and unground blanks. *Stupakoff Div.*

1647. Degreasing
34-page booklet on vapor decreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

1648. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1649. Descaling
4-page reprint 48 on sodium hydride descaling and desanding of ferrous castings and forgings. *Ajax Electric Co.*

1650. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

1651. Dew-Point Recorder
Bulletin 11-11 on dew-point systems for recording or controlling. *Foxboro*

1652. Die Cast Parts
8-page illustrated list of small zinc alloy die castings, special and standard. *Gries Reproducer Corp.*

1653. Die Casting
Illustrated catalog on complete line of die casting machines. *Kux Machine*

1654. Drawing Titanium
6-page reprint on techniques for drawing and other forming methods. Experience with severe forming operations. *Brooks and Perkins*

1655. Ductile Iron
28 page bulletin gives advantages and applications of ductile iron. Properties. *International Nickel Co.*

1656. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

1657. Electric Furnaces
Data sheet describes and gives specifications of standard non-metallic resistor furnaces. *Harrop Electric Furnace Div.*

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Cermets and Ceramics
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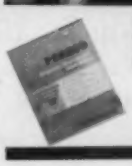
Sectionalized TUBE FURNACE

for coil or strip stock

Assembled of sectional units, each with independent, integral controls, this Pereco Tube Furnace is easily adapted to varying requirements. Sections can be added or removed as needed—or used as separately integrated units. Such flexibility provides for different rates of travel of stock, temperature zoning, prescribed "holding" time, required daily production—or many combinations of peculiar temperature regulation. This unit is typical of the wide range of sizes and types of Pereco Standard or special electric furnaces. Let Pereco recommend equipment for your needs.



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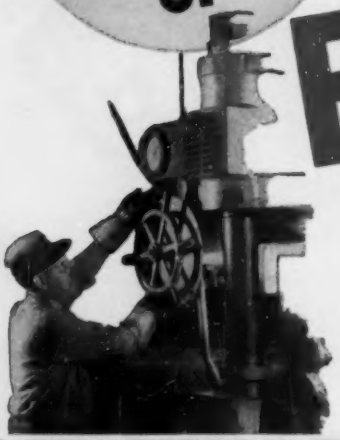
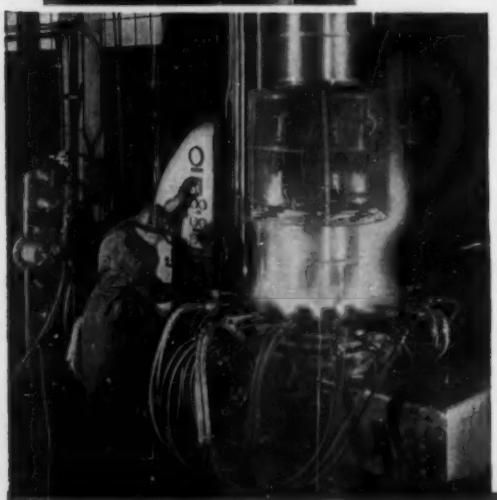


...which ONLY the Commercial Heat Treater can provide



Today's modern commercial heat treating plant might well be described as a "department store" for metal treating services. For under one roof are offered you not only the full range of heat treating equipment for all types of processes . . . but . . . of still greater importance, the manpower skills of the management and technicians of those supervising and performing your jobs. *Service* is their keynote.

Whatever your needs . . . whenever you need it . . .

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Rock Island, Illinois

Standard Steel Treating Co.
Detroit 10, Michigan

Syracuse Heat Treating Corp.
Syracuse, New York

Winton Heat Treating Company
Cleveland 16, Ohio

1658 Electric Furnaces

Bulletin No. 528 on electric furnace for investment casting. Weight of charge, melt time, power consumption for stainless, Stellite, gray iron, copper, brass. *Detroit Electric Furnace Div.*

1659. Electric Furnaces

Bulletin HD-153 on furnaces using silicon carbide heating elements for duty to 2600° F. *Hevi Duty Electric Co.*

1660. Electric Furnaces

8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

1661. Electrolytic Iron

New 4-page folder on uses and properties of 99.9% pure iron. *Van der Horst*

1662. Electron Tubes

Folder on tubes for industry, research and other applications. Separate data sheets give description, operating conditions, constant current characteristics. *Machlett Laboratories*

1663. Electroplating

Bulletins on electroplated gold, rhodium, palladium, platinum, silver, nickel, and analysis of gold and gold alloy solutions. *Technic*

1664. Endothermic Atmospheres

16-page reprint on endothermic atmospheres for heat treatment of steel. Effect of temperature on atmosphere. Calculating analysis. *Electric Furnace Co.*

1665. Extensometer

8-page bulletin on extensometers for sheet metal and wire, compressometers, defectometers and other accessories. *Baldwin-Lima-Hamilton*

1666. Extrusion

Folder describes the hot extrusion process and gives its history. *Jones & Laughlin*

1667. Fabrication

Booklet on welded steel heavy fabrication pictures and describes how various products are made. *R. C. Mahon*

1668. Filters

8-page bulletin on tubular screen, pressure and settling filters, magnetic separators. *Industrial Filtration Co.*

1669. Finishing

16-page bulletin 51 on handling, metal cleaning, precision finishing and baking equipment. *Despatch Oven*

1670. Finishing

4-page bulletin on deburring and finishing cast, machined and stamped parts. Fixturing, shop hints on cutting costs, methods. *Metal Parts Sales Co.*

1671. Finishing

Technical data folder on Roto-Finish process, chips and compounds. Line of standard and special machines. *Roto-Finish Co.*

1672. Finishing Machines

12-page catalog on basic types of automatic transverse spray finishing machines. Basic design, advantages. *DeVilbiss Co.*

1673. Flame Hardening

20-page booklet on precision flame hardening machine with electronic control. Details of operation and applications. *Cincinnati Milling Machine*

1674. Flow Meters

Bulletin 203 on flow meter for gas used in heat treating. *Waukee Eng'g.*

1675. Forgings

12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., Baldwin-Lima-Hamilton*

1676. Forgings

94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

1677. Forgings

Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

1678. Forgings

New 16-page booklet on application of steel forgings—drop, press and upset. *AmForge Div., American Brake Shoe Co.*

1679. Formed Shapes

26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

1680. Freezers

New 4-page folder on six different models. Standard and optional features, temperature ranges, capacities, inside and outside dimensions. *Webber Corp.*

1681. Furnace

Description of new spheroidizing furnace installed at Budd Co., in Metal Minutes, Nov. 1956. *Sunbeam Corp.*

1682. Furnace

Bulletin on new muffle furnace describes insulation, heating and instrumentation. *Hevi Duty Electric*

1683. Furnace

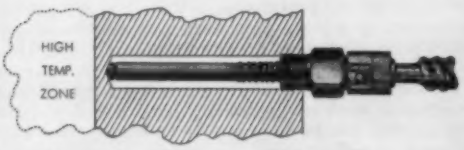
Bulletin T-19A on controlled atmosphere heat treating furnace. *Ipsen*

1684. Furnace Belts

44-page catalog describes metal belts

Bayonet Thermocouples Are Spring-Loaded

Field Proven By Many Years' Successful Use



You always get fast, dependable response from T-E's miniature bayonet thermocouples because (1) spring-loaded hot junctions are always held in tight contact with the measured surface—regardless of expansion and contraction, and (2) the 'couples themselves are extremely sensitive to temperature changes. Available in C-C, I-C and C-A, they are widely used with cylinder heads, extruders, heat transfer lines and other similar applications. Different length adapters permit use of one T/C to measure temperatures at various depths. Pipe-clamp adapters are also available. Bayonet-lock caps provide quick, easy removal. Lead connections are supplied straight or with 45° or 90° angles. All probes and adapters are of stainless steel.

Write for Bulletin 2-H.

Thermo Electric Co., Inc.
SADDLE BROOK, NEW JERSEY
In Canada—THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.

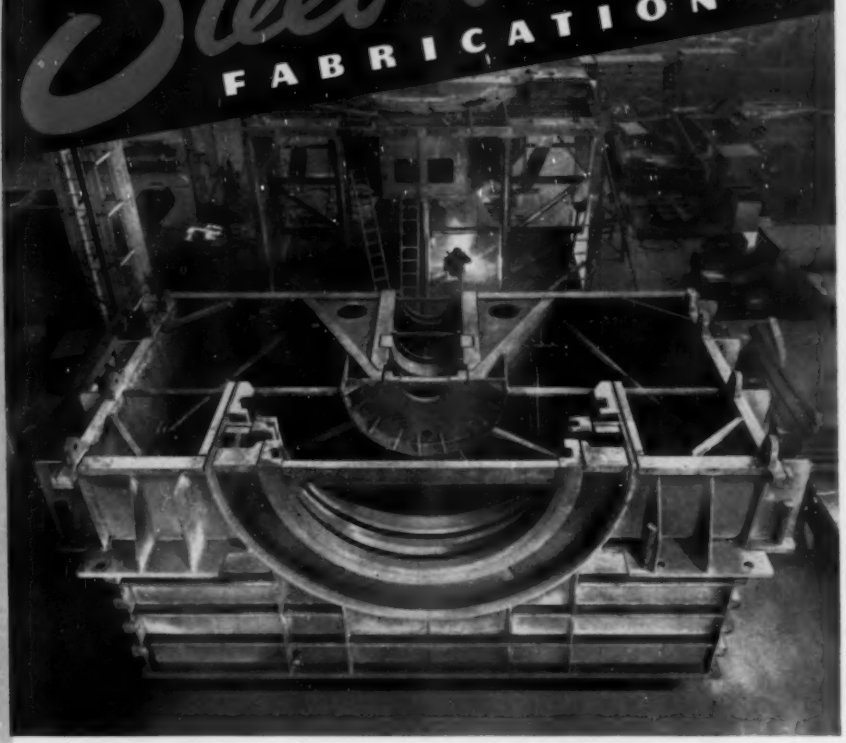
2 Applications (REGULAR AND SUPERFICIAL) 1 Tester

Hundreds of installations over the past few years have proved the economy of the only hardness tester which combines all scales of Rockwell Test (15 to 150 kg. loads).
The Kentrall cuts costs because it does the job of two conventional testers, requires only half the space and maintenance. Write for more detailed information, plus a list of prominent users who have switched to Kentrall. TD148

PRICE $680.

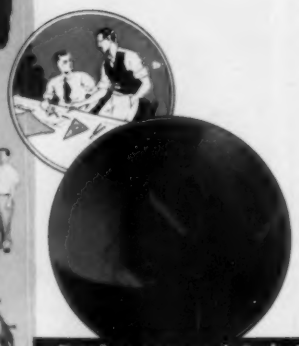
KENTRALL
THE TORSION BALANCE COMPANY
Main Office and Factory: Clifton, New Jersey
Sales Offices: Chicago, San Francisco

Steel-Weld FABRICATION



Use WELDED STEEL for Greater Strength with Less Weight!

The weldment shown above is one half of the base for a 300,000 KW Steam Turbine... it weighs over 100 tons. This base, and the units shown at left, are typical of the thousands of Steel-Weld Fabricated parts and assemblies produced by Mahon each year for manufacturers of processing machinery, machine tools, and other types of heavy mechanical equipment. Are you taking full advantage of the economies offered by welded steel components in your products? In the design of almost any type of heavy machinery, or mechanical engineering project, there are parts and subassemblies that can be produced more economically and more satisfactorily in welded steel . . . because, in weldments you get greater strength with less weight, plus the additional advantages of greater rigidity and 100% predictability. When you consider weldments, you will want to discuss your requirements with Mahon engineers, because, in the Mahon organization you will find a unique source for weldments or welded steel in any form . . . a fully responsible source with complete facilities for design engineering, fabricating, machining and assembling . . . a source where design skill is backed-up by craftsmanship which assures you a finer appearing product embodying every advantage of Steel-Weld Fabrication. See Sweet's Product Design File for information, or have a Mahon sales engineer call at your convenience.



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Sales-Engineering Offices in Detroit, New York and Chicago

Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON

for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1685. Furnace Fixtures
Folder on heat and corrosion resistant trays, boxes and fixtures. Alloys, compositions, maximum temperatures, uses. *Westalloy Div., West Steel Casting Co.*

1686. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

1687. Furnaces
Data on line of melting, heating and heat treating furnaces for ferrous and nonferrous metals. *Loftus Engineering*

1688. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

1689. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1690. Furnaces
Folder on new sizes, specifications for soft metal reverberatory furnaces. *Eclipse Fuel Engineering*

1691. Fused Quartz
New brochure on fused quartz and silica for use in furnaces and laboratory equipment. Properties and how they are formed into usable products. *Amersil Co.*

1692. Gas and Electric Furnaces
Bulletins on furnaces for all types of heat treating and hardening, both standard and custom designed. *Pacific Scientific Co.*

1693. Gas Equipment
New 24-page catalog on industrial gas manifolds with automatic controls. Acetylene generators. Recommended uses and specifications. *Linde Air Products Co.*

1694. Graphite
4-page catalog section S-5050 on impervious graphite and resin-base cements for corrosive service. 2-page table gives recommendations for commercial applications. *National Carbon*

1695. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

1696. Hard Facing
New 4-page bulletin on corrosion resistant hard facing overlays. Processes for applying surfaces; properties of cobalt-chromium-tungsten facings. *Cleveland Hard Facing, Inc.*

1697. Hardness Numbers
Pocket-size table of Brinell hardness numbers incorporating other tabular information. *Steel City Testing*

1698. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

1699. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

1700. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1701. Hardness Testing
Bulletin No. A-18 on Alpha Co. Brinell hardness testing machines. *Gries Industries*

1702. Heat Exchanger
Bulletin 132 on sectional heat exchanger

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with .0005 "SUPERCASE"

Been looking for a parts casing process that gives you a "paper" thin, but extremely hard, wear-resistant surface? You've found it! It's "SUPERCASE" . . . a new process, *exclusive* with Standard Steel Treating Company, for nitriding all types of stainless steels. As in the typical "SUPERCASED" parts illustrated above, normal case depths range from .0003 to .0007 and the hardness factor approaches that of a diamond.

Consider, too, some of the other outstanding advantages of "SUPERCASE" over older nitriding methods . . . case depths are controlled to much finer limits . . . dimensional change is negligible . . . reworking, when needed, simply involves case removal, and selective hardening is easily accomplished by masking off areas that require machining after nitriding. Ask about "SUPERCASE" . . . write Standard for full details today!

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for use with quench bath, annealing furnace, wire drawing equipment and other industrial cooling functions. *Niagara Blower*

1703. Heat Exchangers

Bulletin 105 on heat exchangers, their pressure ratings and heat transfer ratings. *Thermal Research & Engineering Corp.*

1704. Heat Treating

Monthly Bulletin on used heat treating and plating equipment, available for immediate delivery. *Metal Treating Equipment Exchange*

1705. Heat Treating

16-page booklet on cost accounting for heat treating. *Metal Treating Institute*

1706. Heat Treating Aluminum

New bulletin SC-171 on furnaces, soaking pits, annealers, batch units for heat treating, melting, investment casting aluminum and other light alloys. *Surface Combustion*

1707. Heat Treating Fixtures

12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

1708. Heat Treating Fixtures

32-page Catalog G-10 covers heat and corrosion resistant fabricated alloy products. Includes furnace muffles, trays, fixtures, retorts, pit-type furnace equipment, salt bath equipment, pickling and plating equipment. *Rolock, Inc.*

1709. Heat Treating Fixtures

24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1710. Heat Treating Furnaces

12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

1711. Heat Treating Pots

Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

1712. Heat Treatment

Bulletin 200 on car hearth, rotary hearth, pit, roller hearth, belt, chain, pusher and "hi-head" furnaces. *R-S Furnace*

1713. Heaters

Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

1714. High-Strength Steel

Folder on medium manganese copper-bearing high strength steel. Properties. Corrosion resistance. *Youngstown Sheet and Tube*

1715. High-Strength Steels

29-page discussion of progress being made toward higher strength alloy steels. Methods which increase strength of nickel-chromium-molybdenum alloy steel. *International Nickel Co.*

1716. High-Strength Steels

New folder on manganese-copper steels. Properties, fabricating practice. *Republic Steel*

1717. High-Temperature Alloy

14-page bulletin on Udimet 500 gives composition, heat treatment, machinability, hot working characteristics and properties. *Utica Drop Forge and Tool*

1718. High-Tensile Steel

8-page bulletin on properties and composition of N-A-X- high-tensile steel. Examples of resistance to impact, fatigue, abrasion and corrosion. *Great Lakes Steel*

1719. Hose and Tubing

New 64-page catalog provides design suggestions. Specifications, bend diameters, lengths, types. Metals used. *American Brass Co., American Metal Hose Div.*

1720. Induction Brazing

Folder tells how tips of carbide may be brazed on tool shanks. *Ohio Crankshaft*

1721. Induction Heating

8-page bulletin on low and high frequency equipment. Charts on depth of hardness, frequency selection chart. *Magnethermic Corp.*

1722. Induction Heating

High Frequency Review contains article on high temperature fatigue tests using induction heating. *Lepel High Frequency Laboratories*

1723. Induction Heating

12-page booklet B-6519 on equipment for induction heating for forging, hardening, annealing and metal joining. *Westinghouse Electric*

1724. Induction Heating

Folder 15C8053A gives advantages of induction heating and specifications and dimensions of induction heater. *Allis-Chalmers*

1725. Induction Melting

Bulletin 70 on furnace. Controls, designs. *Inductotherm Corp.*

1726. Inspection

Descriptive information and instructions for new inspection process to detect surface flaws on all ferrous and nonferrous metals. *Zaco Laboratories*

1727. Inspection

Bulletin GEA-6520 on new pinhole detector for automatically inspecting fast moving opaque strip for small holes. *General Electric Co.*

1728. Instruments

4-page folder on new micro-microammeters. Models, circuits, specifications. *Keithley Instruments*

1729. Insulators

Bulletin P1-55 on insulators and insulating tubing. *McDanel Refractory Porcelain*

1730. Iron Powder Electrodes

8-page booklet on four new iron powder electrodes shows welding techniques. Current ranges, mechanical properties, deposition rates given in tables. *Champion Rivet*

1731. Lab Test Dies

Complete information on multi-motion laboratory test specimen dies. *Haller, Inc.*

1732. Laboratory Furnace

Bulletin 1016 on single and dual tube furnaces for combustion analysis. *Sentry*

1733. Laboratory Furnace

Box furnace with cooling chamber for use to 3100° F. described in bulletin GEA-4713. *General Electric*

1734. Laboratory Ware

Booklet on stabilized zirconia ware. History of zirconia, properties, composition, porosity. Refractory comparison chart. *Laboratory Equipment Corp.*

1735. Low-Carbon Stainless

"Melting Low-Carbon Stainless Steel" shows advantages in use of new low-carbon chromium alloy for producing extra-low-carbon grades. *Electro Metallurgical*

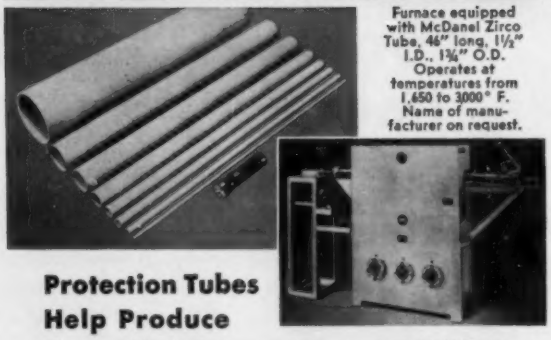
1736. Low-Temperature Alloys

New bulletin on some properties of nickel alloys at low temperatures. Wrought and cast alloys. *International Nickel Co.*

1737. Lubricant

8-page folder describes use of molybdenum disulfide lubricant in cold forming,

McDANEL



Furnace equipped with McDanel Zirco Tube, 46" long, 1½" I.D., 1¾" O.D. Operates at temperatures from 1,650 to 3000° F. Name of manufacturer on request.

Protection Tubes Help Produce Controlled Atmosphere at 3,000° F. In Research Electric Furnace

Experimental sintering, brazing, and heat treating experiments are conducted in this well known laboratory tube furnace, equipped with McDanel Zirco Protection Tube, open at both ends. Sample is heated and cooled within gas-tight tube permitting use of special atmospheres. McDanel Protection Tubes have high resistance to thermal shock and low coefficient of expansion. Special sizes.

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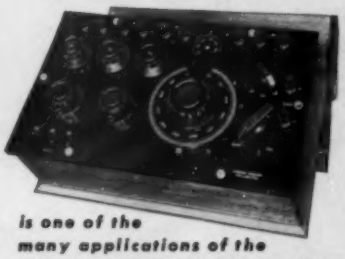
Precise

TEMPERATURE MEASUREMENT



is one of the many applications of the

TYPE B HIGH PRECISION POTENTIOMETER

...a general purpose potentiometer with a number of notable refinements, suiting it particularly to thermocouple work. Distinctive features include:

- Three ranges—0 to 16 millivolts, 0 to 160 millivolts and 0 to 1.6 volts.
- Three reading dials—effective scale length of approximately 175 feet for each range.
- Subpanel switch and slidewire construction for protection of contacts from dust and corrosive fumes.
- Special provisions to minimize parasitic thermal emf's—including automatic compensation of slidewire thermals and gold contacts in galvanometer key.
- Exceptional convenience in reading and adjustment.
- Solid and substantial construction for many years of trouble-free service.

This standard laboratory potentiometer is also well suited for meter calibration, for checking portable potentiometers, and for other critical measurements of D.C. potentials requiring exceptionally high accuracy.

Described in Bulletin 270

SPOTLIGHT GALVANOMETER FOR SHOP AND LABORATORY WORK

- Sturdy, short period
- Sensitive (up to 1.5 μV per mm.)
- Multiple-reflection optical system
- 100-Millimeter scale
- For null or deflection measurements

Described in Bulletin 320

RUBICON COMPANY

Electrical Instrument Makers

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cold heading and other applications. Case histories. *Alpha Molykote Corp.*

1738. Lubricant

4-page bulletin on proper kiln car bearing lubrication and care, recommended lubrication cycles. *Bel-Ray Co.*

1739. Lubricant

Fact sheet on high-temperature lubricant for parts operating in oven temperatures to 400° F. *Tower Oil Co.*

1740. Lubricants

Eighth revision of list of colloidal graphite, molybdenum disulfide and zinc oxide dispersions for industry. *Acheson Colloids*

1741. Lubrication

16-page bulletin 155 on hydraulic oil data and lubrication guide as related to hydraulic presses. Supervision of hydraulic systems, preventive maintenance, oil specifications. *Lake Erie Machinery Corp.*

1742. Machining Alloy Steels

24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

1743. Machining Magnesium

64-page book discusses the various machining operations, machinability, coolants for magnesium. *Dow Chemical*

1744. Machining Titanium

8-page bulletin on turning, milling, drilling, tapping, grinding. Recommendations for each. Typical properties of titanium. *Mallory-Sharon Titanium Corp.*

1745. Magnesium Extrusions

36-page bulletin gives values of moment of inertia, section modulus and radius of gyration of bars, tubing, angles, channels, tees, zees and other sections. *Dow Chemical*

1746. Malleable Castings

Continuing series of information bulletins covering latest techniques and practices in modern malleable casting. *Malleable Founders' Society*

1747. Malleable Iron

Reprint 51-B on metallurgy, treatment and heat treated properties of malleable iron. *Surface Combustion*

1748. Manganese

9-page article on electromanganese. Manufacturing procedures, product characteristics, uses. In Foote Prints, V. 28, No. 2. *Foote Mineral Co.*

1749. Melting Aluminum

Bulletin 310 on furnaces for melting aluminum. *Lindberg Engineering Co.*

1750. Melting Furnaces

New Catalog C5A gives applications and specifications of 10 different types of melters—soft metal, brass, aluminum, crucible type and others. *American Gas Furnace Co.*

1751. Melting Furnaces

28-page catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

1752. Metal Forming

Folder on rolling mills, swaging machines, wire shaping mills, wire and tube drawing machines. *Fenn Mfg.*

1753. Metal Powders

16-page booklet on CDF iron powder. Briquetting characteristics, green strengths, iron sinters, iron-copper mixes, iron-copper bushings and iron-copper-carbon mixes. *Republic Steel*

1754. Metallograph

30-page booklet, E-232, on Balphot all-purpose metallograph—bright field, dark field, polarized light, phase contrast. *Bausch & Lomb*

The door to higher quality, longer wear and greater economy in abrasives . . .

ABRASIVE SHOT & GRIT CO., INC.

Springville, New York

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1755. Metallography
Metal Digest V1, No. 6 and V2, No. 1 describe the Automet attachment for the grinding and polishing of metallographic samples. 28 pages. *Buehler Ltd.*

1756. Metalworking
50-page bulletin 38 on computations for metalworking in presses. Diagrams for computing pressure, formulas and charts on blanking and shearing, drawing and reducing, ironing, coining, sizing, forging, extrusion. *E. W. Bliss Co.*

1757. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

1758. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

1759. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation. *Bausch & Lomb*

1760. Moisture Measurement
12-page bulletin on how to measure water vapor in air and other gases. Gravometric, dew point and wet and dry bulb methods, and others. *Pittsburgh Lectrodryer*

1761. Molybdenum
8-page reprint on arc-cast molybdenum describes machining procedures, tools and equipment. How to machine a turbine wheel. *Climax Molybdenum Co.*

1762. Molybdenum Borides
6-page bulletin on applications, chemical, physical and mechanical properties of refractory molybdenum borides. Preparation of compounds. *Climax Molybdenum*

1763. Nickel Alloy
12-page booklet on Hastelloy Alloy R-235, vacuum-melted wrought alloy containing aluminum and titanium. *Haynes Stellite Co.*

1764. Nickel Wire
6-page handbook on how to design with nickel alloy wire. Case studies, guide to selection of materials. *Techalloy Co.*

1765. Nitriding
Bulletin 204 on pressure nitriding process. Uses, advantages. *A. F. Holden*

1766. Nitriding
Data on process for nitriding stainless steel. *Standard Steel Treating*

1767. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1768. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1769. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1770. Ovens
16-page bulletin No. 53 on various types of core and mold ovens, special ovens and heat treating furnaces. *Carl-Mayer*

1771. Ovens
Two bulletins on bench-type, cabinet-type, truck-type recirculating ovens. Construction, heating systems. *W. S. Rockwell Co.*

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1772. Oxygen Analyzer
Data sheet on continuous-flow type oxygen analyzer. Description, applications, principles of operation. *Consolidated Electrodynamics Corp.*

1773. Phosphating
Folder on phosphating and metal protective coating materials. Purpose and make-up of each type of coating. *Turco Products*

1774. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1775. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g.*

1776. Piping
Data folder TDC-138B on seamless and welded pipe of carbon, alloy and stainless steels. Dimensions, weights, specifications, grade, analyses. *Babcock and Wilcox Co.*

1777. Plating
New data and specification sheet covering tin plating a wide range of nonferrous thin strip metals. *Somers Brass Co.*

1778. Plating Brightener
Literature on zinc brightener used in plating parts by barrel method. *Smoothex, Inc.*

1779. Plating Solutions
Operating manuals for plating with metal fluoborate solutions. *Baker & Adamson.* See page 149

1780. Porcelain Enamel
20-page booklet reviews history of porcelain enamel and describes large volume production of small parts. *Erie Ceramic Arts Co.*

1781. Powder Metallurgy
4-page folder presents extensive powder metallurgy bibliography for 1954 and 1955. *Harper Electric Furnace Corp.*

1782. Powdered Metals
Bulletin 800-B on pre-alloyed iron powders with varied chromium-nickel contents. *Metal Hydrides*

1783. Powdered Metals
24-page booklet on sintered bronze bearings and metal parts. Design hints, machining suggestions. Specifications. *Bunting Brass and Bronze*

1784. Potentiometers
12-page bulletin 270 on several different potentiometers including portable models. *Rubicon*

1785. Precious Metals
Data on bright gold, bright silver, rhodium plating and salts. *Sel-Rex*

1786. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

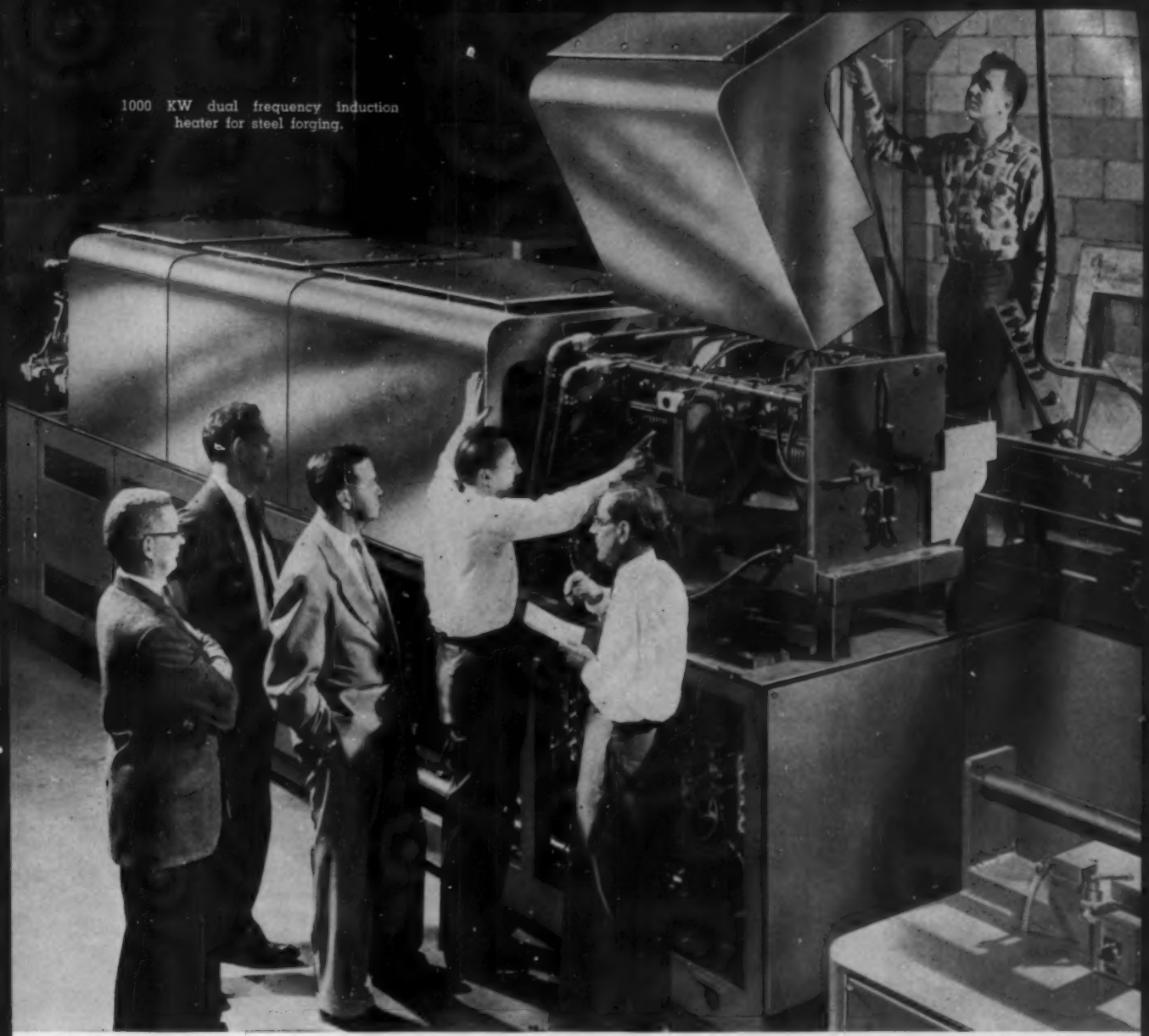
1787. Precision Castings
20-page book on alloys used, specification ranges, advantages and castings made by precision casting. *Haynes Stellite*

1788. Presses
New 40-page booklet on power operated machines for plate and sheet metal work. Specification charts. *Niagara Machine & Tool Works*

1789. Presses
New 12-page brochure on horizontal, multi-station, automatic redraw presses. Details on 12 machines; advantages of multiple station deep drawing; attachments. *Waterbury Farrel Foundry & Machine*

1790. Product File
30 new products and 500 pieces of literature described in 20-page reprint of

(*Continued on page 48-A*)



1000 KW dual frequency induction heater for steel forging.

James McLaughlin, Sales Manager, Low Frequency; Pete Hassell, Sales Manager, High Frequency; John Logan, President; Bruce McArthur, Vice President; Ted Kennedy, Chief Engineer.

the Brass does much more than "TAKE A LOOK"

The Magnethermic brass has a personal interest in this heater.

They have combined their talents on the original design, the application engineering, and the fabrication. Little wonder that they take this close look in the final stages of production.

This procedure is standard—not the exception. All Magnethermic Heaters, large or small, receive day-to-day supervision of the President, Vice President, Chief Engineer and other well-known authorities on induction heating.

Specialized attention to each order for induction heating equipment . . . high, low, or dual frequency can be applied only in a specialized company like Magnethermic where induction heating is the only business.

Induction Heating Equipment 60 to 450,000 cycles

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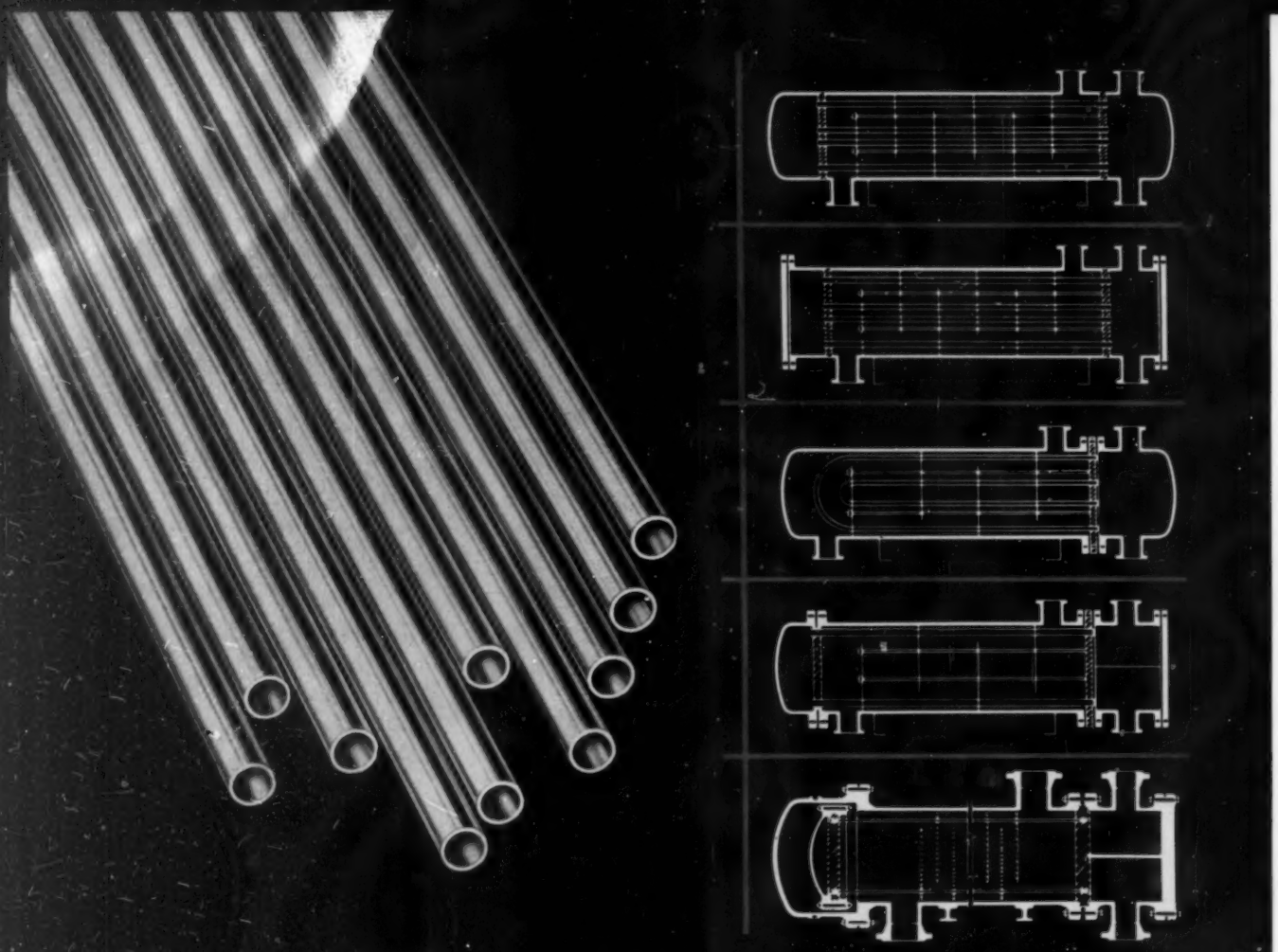

Here's How to Check Corrosion, Prevent Product Contamination

When you have problems of corrosion and product contamination in your heat exchangers and condensers, then it's time to specify B&W Tubing. In an extensive range of processes where these points are key factors, the selection of the best tube steel analysis for the best performance is, in every case, your first requirement.

Because B&W Heat Exchanger and Condenser Tubing is made in a wide variety of carbon, alloy, and stainless steel grades, seamless or welded, and in a full range of combinations of diameters and wall thicknesses to meet practically every requirement, you can select the most economical and dependable tubing for your specific application. Designers prefer B&W Tubing and shop men know from on-the-job experience that it's easy to bend, to roll-in, and to weld.

Call on Mr. Tubes at your nearby B&W Tubular Products Division District Sales Office—let him help you solve your heat exchanger or condenser tube problems. Write for bulletin 329. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

TA-7006-PG3

Seamless and welded tubular products, seamless welding fittings and forged steel flanges — in carbon, alloy and stainless steels

(Continued from page 46)

items appearing in monthly magazine during second quarter, 1957. *Metal Progress*

1791. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

1792. Quench Agitation
Information on mixers and agitators, including units applicable to industrial quenching equipment. *Mixing Equipment*

1793. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

1794. Quenching
Bulletin No. 11 on quenching oil also discusses advantages of quench agitation. *Sun Oil Co.*

1795. Radiography
20-page bulletin on gamma radiography. Uses, sources, equipment. *Nuclear Systems Div., Budd Co.*

1796. Radiography
4-page bulletin on gamma ray camera. Automatic and manual models. *Tracerlab*

1797. Rare Earths
12-page handbook on rare earth chemicals, thorium. Applications of rare earths. *Heavy Minerals Co.*

1798. Recorders
12-page bulletin contains methods of applying 6-in strip-chart recorders for pressure, liquid level, temperature, flow, mechanical motion. *Bristol*

1799. Refractories
Bulletins 320 and 321 on super-refractory for service to 3350° F. and heat-setting foundry patch. *Chas. Taylor Sons*

1800. Refractories
8-page catalog of super refractory shapes, tubes, insulators for use to 3000° F. *Morganite*

1801. Refractories
New bulletin, 1922, on two high temperature Alundum castable refractories. Properties and how to use them. *Norton*

1802. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

1803. Resistance Material
New 16-page brochure on high-temperature electrical resistance heating material. Electrical, chemical and physical characteristics of new cermet material. *Kanthal*

1804. Resistance Welding
New special machine bulletin on 32 multi-spot and projection resistance welding machines. *Taylor Winfield Corp.*

1805. Rust Prevention
Data sheets describe solvent type and emulsifiable type rust resisting compounds. *Swift Industrial Chemical*

1806. Rust Preventives
12-page bulletin on water-soluble rust preventive. *Production Specialties*

1807. Salt Bath Carburizing
5-page booklet on liquid carburizing with advantages and disadvantages of the salt bath process. *American Cyanamid*

1808. Salt Bath Descaling
12-page bulletin B-40 describes continuous and batch descaling lines for removing oxide from steel, bronze, copper, stainless and titanium. *Drever*

1809. Salt Bath Equipment
8-page bulletin on Kolene descaling, desanding and graphite removal processes. *Kolene Corp.*

1810. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1811. Salt Baths
32-page bulletin on salts for tempering, annealing, neutral hardening, martempering and carburizing. Heat treating data. *E. F. Houghton*

1812. Sand Blasting
4-page bulletin 1256 on sand blasting machines for cleaning, deburring, surface preparation. *Leiman Bros.*

1813. Saws
Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1814. Shear
Bulletin on bar and billet shear for rounds, squares, flats, billets and structurals, either hot or cold. *Hill Acme Co.*

1815. Shearing and Slitting
88-page catalog on shearing knives describes different kinds, knife-setting suggestions and clearances. Tables of grinding wheel specifications hardness conversions, standard and tin-plate gages, carbon, alloy and stainless steels. *American Shear Knife Co.*

1816. Shearing
16-page digest on types, sizes and grades of metal cutting knives suited to all types of metal shearing. Care and handling, cutting practice and recommended grades for various operations. *Hill Acme Co., Cleveland Knife Division*

1817. Shot and Grit
14-page catalog describes cast steel, malleable iron, chilled iron, cut wire and other forms of abrasive shot and grit. Methods of shot peening and impact cleaning. *Abrasive Shot & Grit Co.*

1818. Shotblasting
16-page "Primer on the Use of Shot and Grit." Problems of blast cleaning operations. *Hickman, Williams*

1819. Silicon Carbide
8-page booklet on silicon carbide refractory. High-temperature properties. Shapes. Design practices. *Refractories Div., Carborundum Co.*

1820. Slitting
76-page handbook on multiple rotary slitting lines. Design, selection and operation of slitters. Specifications and capacity tables. *Yoder Co.*

1821. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

1822. Soldering Fluxes
4-page bulletin on line of non-acid, self-cleaning fluxes. How they work. *Lake Chemical Co.*

1823. Soldering Fluxes
Discussion in "Federated Metals Digest," Vol. 3, No. 1, of various types and their advantages. *Federated Metals*

1824. Specifications Index
28-page cross index lists copper alloy specifications of nine different Government agencies. *American Brass*

1825. Spray Painting
16-page bulletin on electrostatic spray painting. How it is done. Case histories. *Ransburg Electro-Coating Corp.*

1826. Springs
April 1957 issue of Mainspring carries article on designing springs for performance. Alloys, fabricating methods, requirements. *Associated Spring*

1827. Stainless Steel
Booklet on 430 stainless. Properties, fabrication. *Sharon Steel*

1828 Stainless Steel
4-page data sheet on Type 418 special. Properties, heat treatment, analysis. *Allegheny Ludlum Steel Corp.*

1829. Stainless Steel
24-page booklet on stainless bar and wire. Forms available, grades. Advantages, properties, fabrication, electropolishing, ebonizing. *Armco Steel Corp.*

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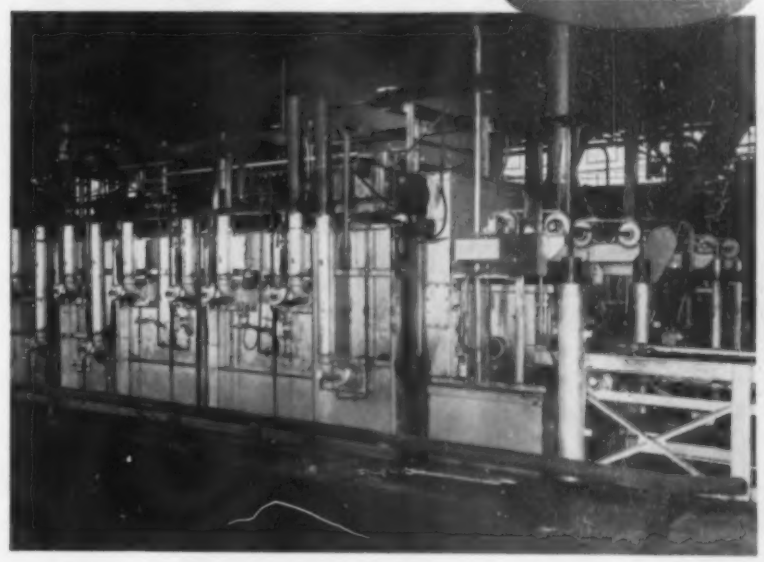

LET'S TALK ABOUT

PRODUCTION DEMANDS

High production demands can be met only when every piece of equipment in the plant is geared to its job. In many plants, the bottleneck is heat treating because furnaces which were modern five years ago are virtually obsolete. These units must be replaced, redesigned, or added to.

Automatic handling of materials is one answer, of course. Today, some heat treating systems are tied right into production lines. In other plants, work is centralized with automated equipment eliminating most stock handling. A single operator loads green work and removes finished parts.

Some furnaces accomplish dual jobs. A recent Holcroft installation was built to temper two entirely different classes of carburized parts. The furnace was designed with a double chamber with each side operating at the required temperature. Flags, placed on the trays requiring low temperature tempering, keyed the line so that the work automatically positioned itself in front of the correct chamber. Another installation featured a double deck furnace—designed so that two entirely different heat treat processes were accomplished in space where but a single furnace would normally go.

And so it goes: a little idea to save a minute or to eliminate a manual operation—a brainstorm that combines two or more furnaces or steps up furnace capacity. This Holcroft concept can help you produce more for less and with better quality. Better write today.

6930

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6545 EPWORTH BOULEVARD • DETROIT 10, MICHIGAN
PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

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CANADA: Walker Metal Products, Ltd., Windsor, Ontario

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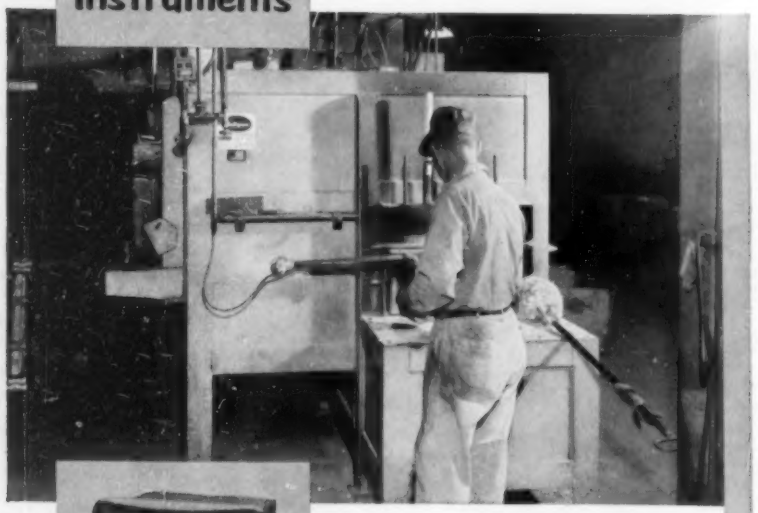
Wheelco Instruments

Close temperature control pays off in operation of aluminum-melting furnace



Wheelco 400 Series Capacitrols maintain precise temperature control in the melting zone and in the metal-holding bath

Here's an aluminum-melting furnace that paid for itself in less than one year's operation. Built by Eclipse Fuel Engineering Co. for a Midwest producer of a broad range of aluminum castings, it replaces three older furnaces and saves $450 a month in operating costs.

Two Wheelco 400 Series Capacitrols play an important role in effecting these savings. By controlling temperature precisely, they keep furnace efficiency and metal quality at high levels.

A wide choice of control forms, using reliable electronic circuits and plug-in components for faster service or maintenance, are yours with Wheelco Series 400 Capacitrols. Call your Wheelco field engineer for help in solving control problems.

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Industrial Instruments • Automatic Controls • Air Distribution Products
Aircraft Controls • Small Motors • Overdoors and Operators • Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

1830. Stainless Strip
32-page brochure on 20 types of stainless strip steel. Recommended applications, chemical, physical and mechanical properties, corrosion resistance. *Superior Steel Corp.*

1831. Stamping Presses
12-page catalog on 200-ton high-speed automatic stamping presses. Engineering drawings and specifications. *Alpha Press & Machine*

1832. Stampings
New 6-page bulletin on intricate progressive stampings. Machines and equipment for their production. *Atlantic Tool & Die Co.*

1833. Steel Bars
Folder gives machinability of C-1144 strain-tempered steel. *Bliss & Laughlin*

1834. Steel Castings
8-page quarterly gives tips on selection of steel castings. Applications of castings. Case histories. *Dodge Steel Co.*

1835. Sub-Zero Treatment
12-page booklet on industrial chilling equipment for shrinking, testing and treating of metals. *Cincinnati Sub-Zero Products*

1836. Sulphur Determination
Bulletin on high frequency combustion unit for determination of sulphur. *Lindberg Engineering*

1837. Temperature Control
8-page bulletin on temperature control systems contains selection guide, terminology, types of control systems. *Wheelco Instrument Div.*

1838. Temperature Control
New Bulletin 72 on temperature monitoring systems. Standard subassemblies and their arrangement to form an integrated temperature monitoring system. *Thermo Electric Co.*

1839. Tempilstiks
"Basic Guide to Ferrous Metallurgy," a plastic laminated wall chart in color. *Claud S. Gordon*

1840. Testing Equipment
80-page illustrated catalog lists over 130 testing and measuring tools for laboratory and production-line use. *General Electric*

1841. Testing Machines
8-page guide to Riehle testing machines and instruments. *Riehle*

1842. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

1843. Thermocouple Alloys
20-page booklet on chromel-alumel alloys gives sizes, temperature-millivolt equivalents, standards, applications. *Hoskins Mfg.*

1844. Thermocouples
32-page file book on pyrometer accessories. Selection of thermocouple and protective tube. *West Instrument Corp.*

1845. Thickness Gage
Folder on pocket-size gage. How to use it. *Ferro Corp.*

1846. Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

1847. Titanium Tubing
12-page folder TDC-185 on seamless titanium metal pipe and tubing. Ranges, tolerances, properties. *Babcock & Wilcox*

1848. Tool Steel
44-page stock list is indexed and includes sizes, weights, and analyses. Decimal conversion and hardness conversion tables. *Uddeholm*

1849. Tool Steel Guide
70-page brochure includes information on 50 types of tool steels and cold finishing products. *Vanadium-Alloys Steel*

1850. Tool Steel Selector
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

1851. Tool Steels
4-page data sheet on Oilgraph-EZ, sulphur-bearing oil hardening graphitic tool steel. Heat treatment. *Allegheny Ludlum Steel Corp.*

1852. Tubing
Data Memorandum No. 4 on large diameter thinwall tubing in seamless and Weldrawn grades. Applications. *Superior Tube*

1853. Tubing
New book on production of seamless and welded tubing. Forging and fabricating operations. *Ohio Seamless Tube*

1854. Tukon Tester
12-page bulletin DH-328 on Tukon micro and macro hardness testers. *Wilson Mech. Inst.*

1855. Tungsten
New 12-page booklet on tungsten coil products for electronic and lighting applications. *Sylvania Electric Products, Inc., Tungsten and Chemical Div.*

1856. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

1857. Ultrasonic Machining
16-page bulletin lists typical machining operations, materials which may be machined ultrasonically, machine features and accessories. *Sheffield Corp.*

1858. Ultrasonics
8-page reprint on improvement in electroplating due to ultrasonics. *General Ultrasonics*

1859. Vacuum Calculator
Slide rule for quick calculation of data necessary in vacuum engineering and processing—for instance, pump capacities and time to reach given vacuum. Pertinent conversion tables on back. *F. J. Stokes Machine*

1860. Vacuum Furnaces
Articles on commercial vacuum furnaces for metals and alloys and some aspects of vacuum melted metals. *National Research*

1861. Vanadium in Steel
189-page book on properties of ferrous alloys containing vanadium and their applications. *Vanadium Corp.*

1862. Welding
24-page booklet on electric resistance welding of butane gas containers. Procedures, metallurgical advantages. *Sciaky Bros., Inc.*

1863. Welding
12-page booklet on three-phase resistance welding machines. Operational principles, associated control equipment. *Taylor-Winfield Corp.*

1864. Welding Electrodes
84-page pocket-size booklet describes characteristics, coating, sizes of various electrodes and compares them with standard designations and other electrode brand names. *Harnischfeger*

1865. Welding Equipment
Catalog on Cadwell process and arc-welding accessories. *Erico Products*

1866. Wire Mesh Belts
130-page manual on conveyor design, belt specifications, metallurgical data. *Cambridge Wire Cloth*

1867. X-Ray Microscope
New catalog includes micrographs, theory of operation and technical details. *General Electric X-Ray Dept.*

1868. Zirconium
7-page bibliography on properties of zirconium and its alloys. *Columbia-National Corp.*

June, 1957

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1588	1614	1640	1666	1692	1718	1744	1770	1796	1822	1848	

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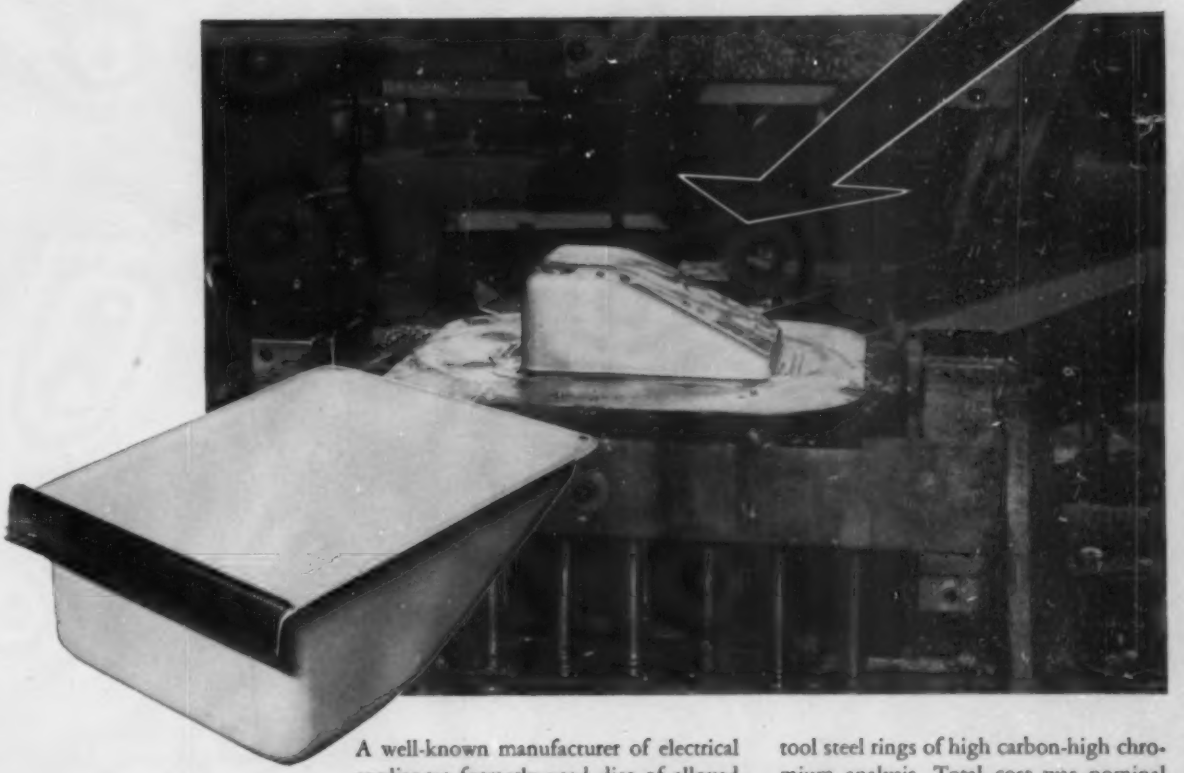
Postcard must be mailed prior to Sept. 1, 1957. Students should write direct to manufacturers.

Here's how A-L CAST-TO-SHAPE TOOL STEELS solved a serious scrap problem on this job



A well-known manufacturer of electrical appliances formerly used dies of alloyed ductile iron castings to draw refrigerator crisper pans.

These dies had to be redressed after every 10,000 pieces (approximate cost: $1300 each) and had to be replaced after every 30,000 pieces. 8 to 10% of the pans were scrapped due to defects.

Because of this scrap problem and the severity of the draw—a 52% reduction of the steel—it was decided to rebuild the dies using a suitable grade of tool steel.

A 2" cut was taken off the top of the old cavity and the draw ring. These cuts were replaced with A-L Cast-to-Shape tool steel rings of high carbon-high chromium analysis. Total cost was nominal compared with buying entirely new dies.

Each of the revised dies has produced approximately 500,000 pans. Their condition indicates that probably *twice* that many can be drawn before the dies must be redressed. Defective pieces have been reduced to a mere 1½ to 2%—*an 80% reduction!*

● Ask your A-L representative TODAY how Cast-to-Shape tool steel can help solve your production problems . . . or write *Allegheny Ludlum Steel Corporation, Forging and Casting Division, Detroit 20, Mich.*

SEND FOR THIS NEW CATALOG

"FORGING AND CASTING PRODUCTS"

Contains the latest information on FCC Air Hardening, Oil Hardening and other Cast-to-Shape Tool Steel Specialties that can save you time and money . . . also Composite Die Sections and Smooth Hammered Forgings in a wide range of tool and stainless steels. *Get your copy NOW*

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For complete **MODERN** Tooling, call

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AL FINE TOOL STEELS SINCE 1854

A Boeing B-47 Stratojet medium bomber gets a take-off assist from 30 Phillips Petroleum Company M15 JATOs.

N-A-X HIGH-TENSILE is readily formed and welded. Here, before welding, a worker sizes the container's aft head, drawn by a 250-ton press. Bottom forging is locked in.

N-A-X HIGH-TENSILE STEEL FORMS AND WELDS READILY

Formability: Even at the higher strength levels (50% greater than mild carbon steel) this material can be cold formed and drawn into very difficult stampings and cold formed shapes.

Weldability: Its weldability by any process is excellent, maintaining toughness through a wide range of temperatures. Under-bead cracking tests are excellent. Using American Welding Society standard bead-weld testing, shows under-bead hardness rises only to 95 Rockwell from 80-85 Rockwell prior to welding.

Make *your* product better, too—
with this high-strength steel

How N-A-X® HIGH-TENSILE STEEL

supplied the money-saving answer to a critical take-off problem

JATO rockets boost heavily laden planes into the air faster, let them operate from shorter runways. A new JATO developed by Phillips Petroleum Company required a case that would endure a pressure of 1,000 pounds per square inch at the high blast temperatures. Yet it must be lightweight, easily fabricated, economical.

In 1954, 100 JATO cases of N-A-X HIGH-TENSILE steel were tested at Air Force Plant 66 near McGregor, Texas, where Phillips Petroleum is contractor-operator.

Result: The N-A-X HIGH-TENSILE case passed every test with flying colors. It *surpassed* the required standards for strength by as much as 20 percent.

The high-strength characteristics that make N-A-X HIGH-TENSILE a better steel for JATO fuel containers also make it better for many other types of pressure containers, where high strength and lighter weight are equally important. It is particularly suitable for Propane cylinders and pressure vessels for the chemical, automotive and oil industries, that must withstand severe interior pressures and handling abuses . . . and for such products as truck and trailer frames, wheels and bumpers, railroad and earth-moving equipment, shipping containers, pipe, and many others.

Other Important Advantages: N-A-X HIGH-TENSILE STEEL, compared with carbon steel, is 50% stronger • has high fatigue life with great toughness • is more stable against aging • is more resistant to atmospheric corrosion. It polishes to a high luster at minimum cost • has greater resistance to abrasion or wear • offers greater paint adhesion.

With N-A-X HIGH-TENSILE you can design longer life, strength with lightness, and economy into your products. Let us show you how.

COMPANION HIGH-STRENGTH STEEL IN THE N-A-X FAMILY

N-A-X FINEGRAIN. A low-alloy high-strength steel ideally suited for applications where the enhanced resistance to atmospheric corrosion of N-A-X HIGH-TENSILE is not required.

N·A·X
HIGH-TENSILE STEEL

N-A-X Alloy Division
GREAT LAKES STEEL CORPORATION
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NATIONAL STEEL CORPORATION

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Great Lakes Steel Corp., Detroit 29, Mich.

☐ Please send me 8-page illustrated technical catalog on N-A-X HIGH-TENSILE Steel.

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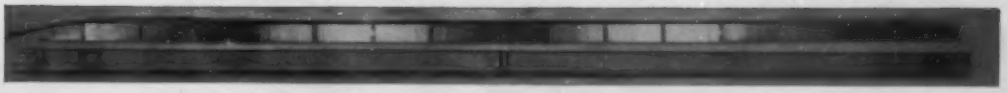
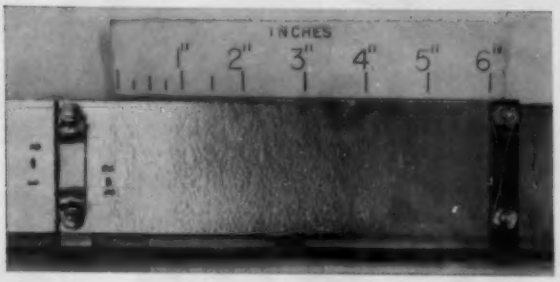
Fred Bingman, Metallographer, prepares metallographic specimens of irradiated materials by remote operation inside a shielded metallographic facility in the Bettis Atomic Power Division hot lab.

An Experimental Fuel Study of Uranium Alloys





A typical test array of instrumented uranium alloy fuel plates.

At Bettis Atomic Power Division laboratories, engineers and scientists are conducting basic research in the field of solid state physics and metallurgy to determine the behavior of nuclear materials under actual reactor conditions.

The experimental fuel plates shown on this page represent the initial step in a study of the temperature dependence of fuel materials to fission gas induced volume changes. These plates on an uranium-niobium alloy have been fabricated with thermocouples in the interior of the plates for constant temperature monitoring. The fuel enrichment is varied to provide the range of fuel temperature and fissioning rates of interest. The samples are being irradiated in a high temperature-high pressure recirculating water system at the NRX reactor site of Atomic Energy of Canada, Ltd., at Chalk River, Canada. The experiment will provide, in addition to data on fuel volume changes, information on neutron induced phase transformation kinetics and crystallographic changes.

This experimental fuel study is part of a joint program between the United States Atomic Energy Commission and Atomic Energy of Canada, Ltd. Bettis Plant conducts similar tests on nuclear fuel, control rod, and structural materials at other sites throughout the United States.

One of the foremost problems that face Bettis metallurgists is the dimensional stability of fuel materials under conditions of high temperature and high fuel burnup. Some of the experiments in connection with this problem include in-pile studies of phase transformation kinetics and fission gas diffusion rates. They also employ remotely operable X-ray and metallographic techniques in the post-irradiation analysis of samples of this type.

This is only one example of the challenging work conducted at Bettis Atomic Power Division. To investigate the excellent opportunities offered by the leader of the nuclear power industry, address your résumé to: Mr. M. J. Downey, Bettis Atomic Power Division, Westinghouse Electric Corporation, Dept. A-167, P.O. Box 1468, Pittsburgh 30, Pa.

Also, outstanding young metallurgists should write today for a descriptive brochure on our unique doctoral fellowship program in cooperation with Carnegie Institute of Technology.

BETTIS ATOMIC POWER DIVISION

Westinghouse

Next month—The Research and Development of Nuclear Fuels—A Study of Property Changes Under Radiation at Low Temperatures.

Integral Cam Programmer . . . Enables complete 1-to-24 hour program to be precast. Electric or pneumatic control on one or both pens.

Millivoltmeter Pyrometer—Vertical Case . . . Available in a variety of electric control forms.

Flame Safeguard Relay . . . Stops flow of fuel into combustion space when flame or ignition fails.

Millivoltmeter Pyrometer—Horizontal Case . . . Fits standard relay rack for easy mounting. Also available with dual set point.

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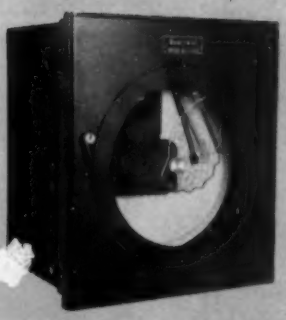
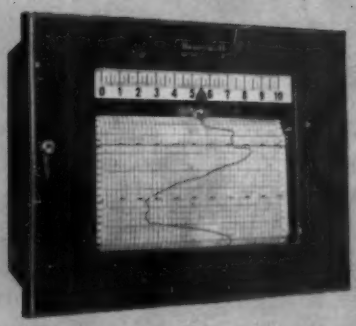
Radiation Detector . . . Responds to 98% of any temperature change within 2 seconds . . . high-speed model responds in half second. For applications from 200 to 7000F.



Circular Chart Program Controller . . . With integral cam index guide. Available with electric and pneumatic control forms.

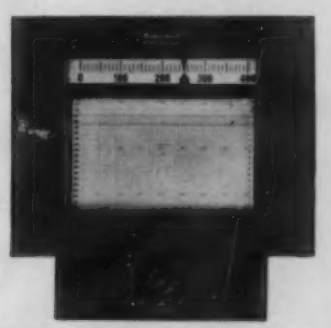
Heavy Duty Electric Motor . . . For operating valves, dampers, louvers and other final control elements.



Strip Chart Recorder—Single or Multiple Point . . . Records all types of variables. Choice of pen speeds and chart speeds.

Precision Indicator—Circular Scale . . . Highly accurate indicator for all variables, one to 48 points.

Circular Scale Controller . . . Scale is over 2½ feet long. Control index rotates with scale for 12 o'clock control check. Available in all electric control forms.



Strip Chart Program Controller . . . Incorporates temperature indication, single or multiple recording, controlling—in one instrument.

STOP shopping . . .

Whether it's temperature, pressure, flow, or any other important variable you want to measure or control, Honeywell makes just the instrumentation for you. Our line of instruments is as broad as your requirements . . . you can choose exactly what you need.

This means you get all the instrumentation you require from a single source, so there is undivided responsibility for the complete installation. And you are assured that equipment suggested for your process is recommended without bias. With a complete line there is no need to over-sell or under-equip.

For the new process, the modernization program, or a replacement problem, find out how Honeywell can go to work . . . anywhere in the metal processing industry. Get in touch with your nearby Honeywell sales engineer. He's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

Precision Indicator—Vertical Scale . . . Has drum-type power-driven scale. Full scale travel in 12 or 4½ seconds.

Honeywell

H HONEYWELL *First in Controls*

DIFFERENT COMPOSITIONS of G-E Neutralene gas are possible to fit various applications—annealing, hardening, brazing, sintering, and carburizing. G-E gas producers shown are rated at 15,000 CFH; complete line includes ratings from 200 CFH.

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OXIDES REDUCED when parts are bright annealed in Exalene gas. Pan on left is shown before cleaning; center pan, after pickling only; pan on right, after bright annealing only. Exalene gas is used also in normalizing, hardening, brazing, and sintering.

SCALE-FREE UNPITTED drill chuck on right was hardened in Thermalene atmosphere, does not need subsequent cleaning; chuck on left was hardened in air. Thermalene gas is used also in bright annealing, normalizing, brazing, sintering, and carburizing.

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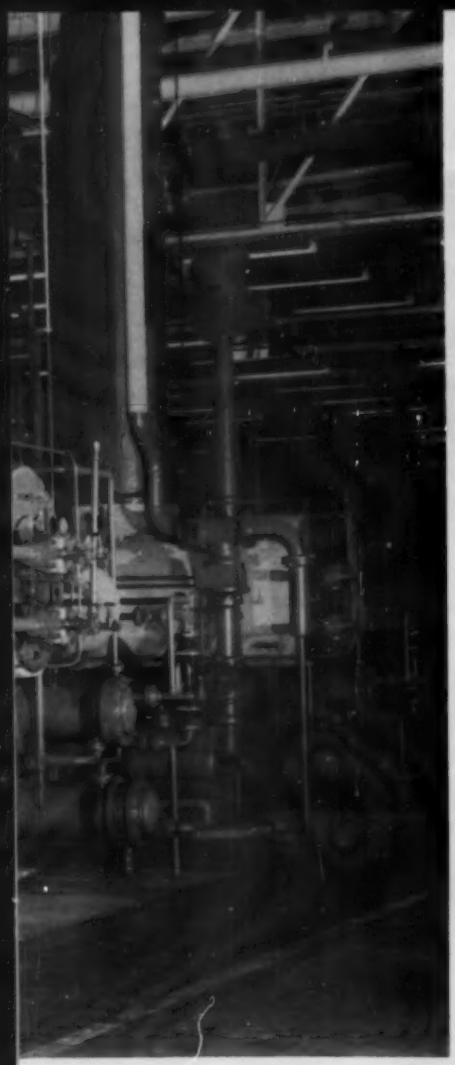

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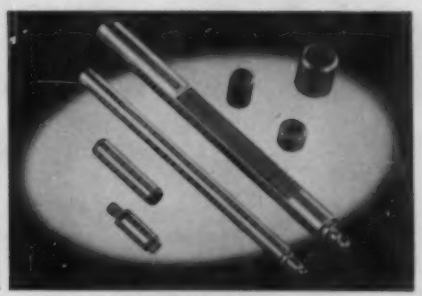

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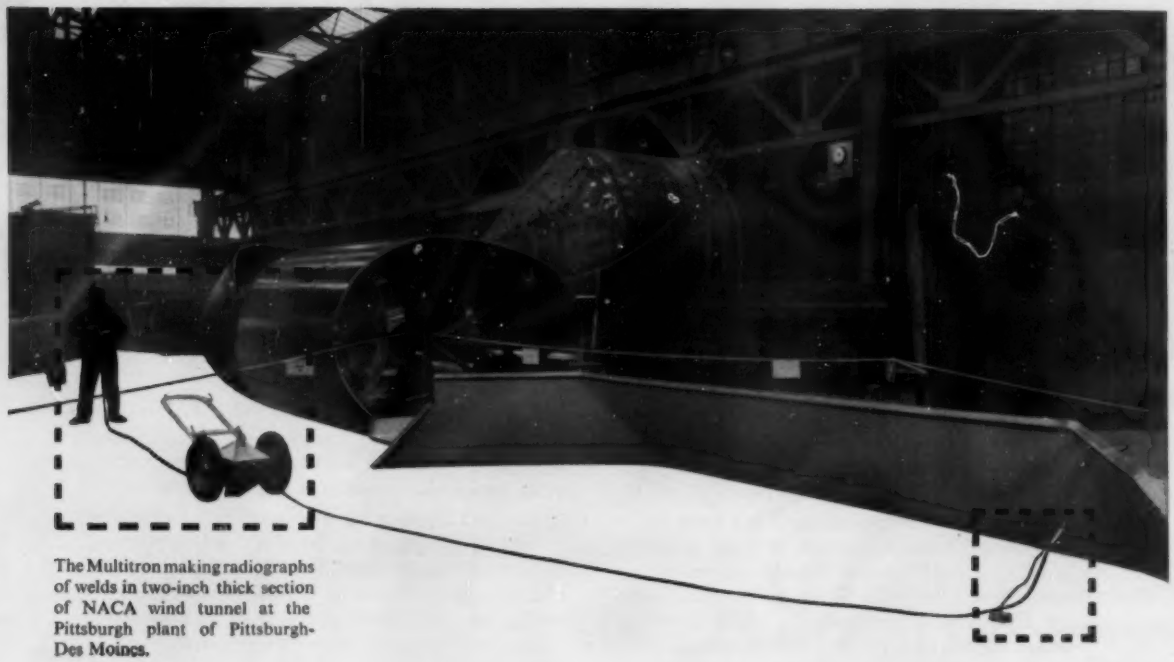

The Multitron making radiographs of welds in two-inch thick section of NACA wind tunnel at the Pittsburgh plant of Pittsburgh-Des Moines.

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Metal Progress
Volume 71, No. 6 June 1957

Metallurgical Aspects of Calder Hall

*By TOM BISHOP**

The first nuclear power plant in the world to produce electricity for general use on a large scale has gone into operation smoothly and satisfactorily, and is fulfilling all the best hopes of its British designers. Metallurgical problems solved include uranium fabrication and canning, selection of steels for pressure vessels, their erection and stress-relief. (W11, T11, 17-7)

BRITAIN IS TODAY facing an urgent need for industrial nuclear energy almost as a matter of national salvation. While the consumption of coal per unit of electricity produced has fallen from about 4 lb. to less than 1 lb. in the past 50 years, the consumption of electricity per head of population has increased about 30-fold. Coal production is inevitably falling. About 10% of all British industrial production is now based on oil, and her dependence upon it was forcibly brought home by the recent Middle East crisis. Moreover, Britain does not have the dollars to purchase American oil in any increasing quantity. So, the full exploitation of power production from nuclear energy is an urgent "must".

At Calder Hall in Cumberland, England, the first nuclear power plant in the world to produce electricity for general use on a large scale started its first reactor on May 22, 1956, within sight of the ruins of Calder Abbey (Fig. 1), built in the 12th Century by the Cistercian monks. Steam generated from the heat of fission was first turned into the turbines on Aug. 20. On Oct. 17 Her Majesty the Queen turned the nuclear power thus generated into the distribution network for use by the general public. A second reactor has now been added, bringing the total generating power up to 92,000 kw.

The original £300 million ($840,000,000) ten-year policy for the nuclear power program introduced two years ago is to be greatly expanded.

*John Miles & Partners (London) Ltd., Consultants to Metallurgical Industries, London, England.

Fig. 1 – The Ruins of Calder Abbey, Built in the 12th Century by the Cistercian Monks, Stands Within Sight of Calder Hall

The main emphasis will be on more powerful stations. The 2,000,000 kw. estimated from the original 12 stations planned will be raised to between 5,000,000 and 6,000,000 in a total of 19 stations, equivalent to a saving of about 18 million tons of coal a year. The expanded power output will be obtained from greatly improved versions of the Calder Hall type of gas-cooled reactor, which will be the backbone of Britain's atomic power program for some years.

The decision to build the graphite-moderated, gas-cooled type of pile rather than the liquid-cooled reactors was largely governed by safety factors in the thickly populated United Kingdom. An advanced type of fast reactor, cooled by liquid metal, is being built, however, at Dounreay, Scotland, for both electricity generation and atomic fuel production.

Metallurgical Problems* – The range of metals involved in atomic energy is determined by a number of factors – irradiation stability, thermal stability, sheathing features, corrosion, fabrication, alloying and physical properties. Metals of direct interest are given in the following list, adapted from "Metallurgical Research in Nuclear Power Production", by J. G. Ball, *Journal*, Institute of Metals, Vol. 84, 1955-56.

U, Pu, Th – Fissile or fertile metals.

Al, Mg, Zr, Be – Metals with low capture cross section for thermal neutrons; used as canning materials for thermal reactors. Beryllium is also used as a moderator.

Cb, Mo, Ta, V, W – Refractory metals for use in fast reactors where their capture cross sections are acceptable. Columbium also has possible use in thermal reactors.

Na, Na-K alloy, Li, Bi – Liquid metals to be used as heat transfer mediums. Bismuth is the favored solvent for the fuel in a liquid-metal reactor.

Constructional steels – Range is from mild to fully austenitic steels, chosen for weldability, resistance to particular corrosive conditions, cost and other factors.

Cermets – Normally used as fissile or fertile materials or as a mixture of fertile, fissile and moderating elements.

The problems which faced the metallurgists concerned with the Calder Hall graphite-moderated, gas-cooled pile in its design stage, can be divided into four parts:

1. Economical fabrication of the uranium into precise form.
2. Attainment of the correct metallurgical structure to insure that the fuel element retains its shape – within acceptable limits – throughout its working life.
3. Provision of an appropriate sheath or can.
4. General problems associated with the reactor as a whole, bearing in mind the possible effects of radiation damage, and compatibility.

Uranium Fabrication

Problems in the fabrication of uranium differ only in degree from those of other metals, primarily because of its rapid reaction with air and its anisotropic plastic properties. These problems were overcome by vacuum casting. Castings made before 1951 included rods 5 ft. long by ⅝ in. diameter, complicated castings weighing up to 500 lb., and tiny castings with ruling sections of approximately 0.05 in. Furthermore, castings could be made with a dimensional accuracy of ± 0.004 in. per in., so that the only machining operation was the removal of runner or riser. Other fabrication techniques investigated included rolling, for which special

*For more detailed engineering and metallurgical data, see the proceedings of a symposium on the Calder Hall plant, held in London on Nov. 22 and 23, 1956, being published in the April and July 1957 issues of the quarterly *Journal* of the British Nuclear Energy Conference.

roll pass shapes to reduce tensional stresses were developed, extrusion (which could be carried out to the same accuracy as casting), swaging, and tube drawing.

The radiation behavior of uranium can be predicted from a knowledge of its structure, explained theoretically (although more than one mechanism has been suggested) and controlled by metallurgical processes. The outcome of much research is that irradiation distortion effects can be minimized by the production of a fine-grained randomly oriented structure. Methods of grain refinement and randomizing were developed from a study of the effect of varying rates of cooling from the beta and gamma phases. If a 1-in. diameter bar of the comparatively impure metal available before 1951 was quenched in water from 1380° F., adequate refinement was produced. Later investigations have shown that the high-purity metal now in use cannot be fully refined in this way but must be alloyed with beta-soluble elements, of which the most effective is chromium.

Shape changes are important at low irradiation doses (up to 0.3% burnup) and low temperatures. At longer irradiations and higher temperatures, fission products can cause large increases in volume and finally disruption, to form a coke-like mass.

With the fine-grained material finally chosen for reactors, straightness of bars is mainly influenced by the mechanical and thermal treatment. In particular, extremely careful alignment of the induction heat treatment equipment is critical. Close attention has been paid to the design and operation of this plant with the result that the straightness of the bars is approaching the point where further improvement would have negligible effects on the bowing stresses of the bars when loaded as struts in service.

Uranium Canning

Second only to irradiation damage come the problems of canning – providing a container for the uranium. The requirements are not easily met. They are:

1. A low cross section to thermal neutrons.
2. Good resistance to coolant attack.
3. Compatibility with the uranium under operating conditions.
4. Good sealing characteristics to protect the uranium from attack by the coolant gas, and to prevent escape of fission products.
5. Good ductility combined with adequate strength to resist or accommodate stresses imposed by the fuel during operation and in some instances to help support the uranium.
6. Good thermal conductivity and extended coolant surfaces for heat transfer.

Uranium is attacked by air at temperatures of about 160° F. while above about 660° F. the rate is such that the reaction is self-sustaining. Rates are lower with other possible coolant gases, but not negligible. A further problem results from the alloying behavior of uranium at operating temperatures with most metals of low cross section that are readily available and easily fabricated. It alloys with aluminum at temperatures above 345° F. and with iron and nickel above 930° F., forming eutectics that melt just above 1300° F.

Much of the earlier work on canning was concerned with the formation of the uranium-aluminum alloy and with the development of interlayers to prevent this interaction. From this and other work on the compatibility of uranium with other metals emerged the fact that there appeared to be no reaction with magnesium.

Oxidation tests were therefore carried out on various grades of pure magnesium and on all commercially available alloys. High-purity magnesium (99.95%) was the most resistant of all materials tested, followed closely by AM 503

Fig. 2 – Calder Hall, Britain's First Nuclear Power Station, Started Generating Power for Industrial Use on Oct. 17, 1956. The reactor shown in the center is one of two. Structures at left are the cooling towers

(containing 1.5% Mn); unless their oxidation behavior was significantly affected by irradiation, both materials appeared to be satisfactory for operation up to 750° F. Further investigation led to an improved series of alloys known as Magnox (magnesium – no oxidation).

Development of Magnox – The high fuel temperature and heat rating involved focused attention on the possibility of a magnesium fire. Although the fire hazard with CO_2 did not appear to be significant during normal operation of the reactor, it was felt that a fundamentally oxidation resistant alloy – even in the molten state – should be used as canning material. A consideration of certain theoretical factors associated with diffusion in ionic solids suggested that the oxidation behavior of magnesium could be improved by certain alloying elements. A number of alloys containing beryllium, calcium and aluminum – nominally 0.05%, 0.1% and 1.0% respectively – were produced from the two standard grades of pure magnesium, melted in steel, graphite and plumbago crucibles. These alloys were tested in air at 1025, 1085 and 1140° F. for periods of 24 hr. The alloys containing beryllium and calcium showed improved resistance to attack over those containing one constituent only, and great superiority over the pure metal.

Fig. 3 – Crack Length in Weldability Tests as Affected by Composition of Magnox Alloys. The white band includes a number of compositions varying between 0.1 and 0.4% Ca

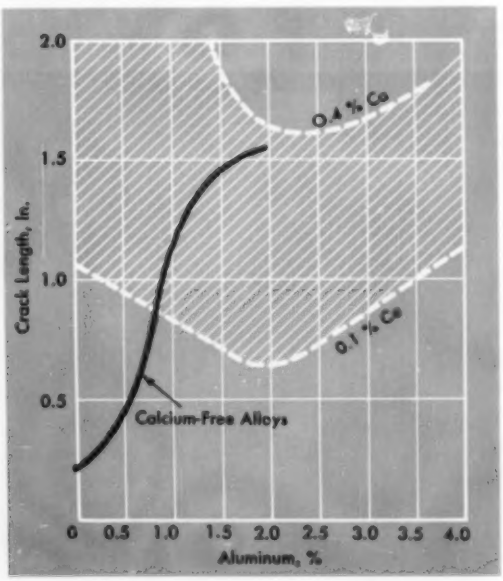

Fig. 4 – Uranium Fuel Element Enclosed in Finned Can Made of Magnox Magnesium Alloy

The tests at 1140° F. were continued with the alloys containing both beryllium and calcium. The time required for the protective film to break down varied between 200 and 800 hr. Once the protective film had broken down, the specimens failed completely within 24 hr. Further experiments on molten Magnox alloys using pure magnesium as the base were made by melting in a bunsen flame and in an electric furnace. The molten metal was covered by a protective film in the same way as aluminum.

Tests on a welded specimen showed that its oxidation resistance was unimpaired. Finally, tests in wet carbon dioxide gave the important result that no failure occurred in 2500 hr. at 1140° F. A minimum of 0.02% Be and 0.07% Ca confers immunity from breakdown in moist air for 24 hr. at 1110° F.

The presence of some aluminum appeared desirable both to increase the strength at operating temperatures, and to facilitate introduction of beryllium, and a Magnox alloy containing nominally 1% Al, 0.1% Ca and 0.05% Be (designated Magnox E) was suggested. This, however, was prone to weld cracking. Weld-

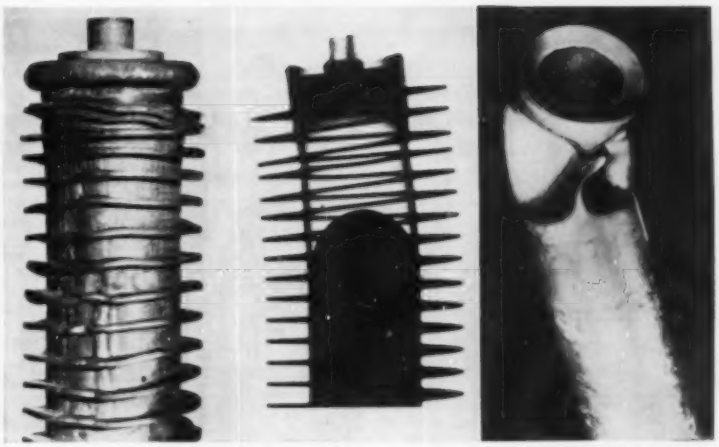

Fig. 5 – Distortion Caused by "Ratcheting". Finned fuel element can at left; severe distortion in experimental finless can at right. Center is X-ray showing ratcheting caused by greater expansion of the magnesium can than the uranium fuel element

ability experiments were therefore carried out on alloys containing varying amounts of calcium, aluminum and beryllium. Satisfactory welds were obtained on alloys containing 1.0% Al, 0.04% Be and 0.05% Ca max.

Figure 3 illustrates the role of both calcium and aluminum in promoting cracking, and suggests that calcium be kept to a minimum or omitted and that aluminum should not exceed 1% (Magnox C type). The important role of calcium in stabilizing the protective oxide film also affects the weldability since it tends to prevent the running together of the two parts when molten.

The effect of contamination of magnesium alloys by stray metals was investigated since it was found early in the development work that small particles of lead, silver and aluminum could lead to extensive damage to magnesium at high temperatures. Equilibrium diagrams indicate that all metals in the B and earlier A subgroups of the periodic table must be classed as undersirable and not allowed to come into contact with the can. The only common structural materials completely compatible with magnesium over a wide range of temperature are mild steel and stainless steel.

Complete penetration of the can with consequent oxidation of the uranium fuel may be expected above the following temperatures for the contaminants listed:

Tin	390° F.
Lead, bismuth	480
Cadmium, zinc	570
Aluminum, calcium	750
Silver, copper	840
Nickel	930
Mercury	Suspect at all temperatures

The effect of exposure to magnesium on the thermo-electric characteristics was found to be insignificant with precious metals and chromel-alumel thermocouples at 750° F. but above 930° F. all thermocouples require sheathing.

Although the danger of contamination does not preclude the use of magnesium alloys, it demands strict cleanliness with respect to foreign metals and this has been rigorously observed for the Calder reactors.

Can Fabrication

The method of fabrication of the can depends on its design. Figure 4 shows a finned Magnox can enclosing the uranium fuel element. Since it was not certain at first what type of fin would give optimum heat transfer properties, all types had to be studied. Cans with longitudinal fins were made successfully by hot mandrel extrusion to any required length but such a process was not possible for transverse fins.

Thread rolling by the "Integron process" of tube manufacture was investigated for fabricating transverse-finned cans and the initial results were promising; if the thread rolling was carried out to produce a finished fuel element rather than a separate can, a mechanical bond was obtained. However, it was thought that sufficiently high and fine finning could not be obtained within the time available, and this method was abandoned in favor of machining from extruded bar. The process developed at the British Atomic Energy Research Establishment consists of boring the central hole followed by fin milling on a mandrel. To save material, experiments were carried out on extrusion of thick-walled magnesium tube, but these were

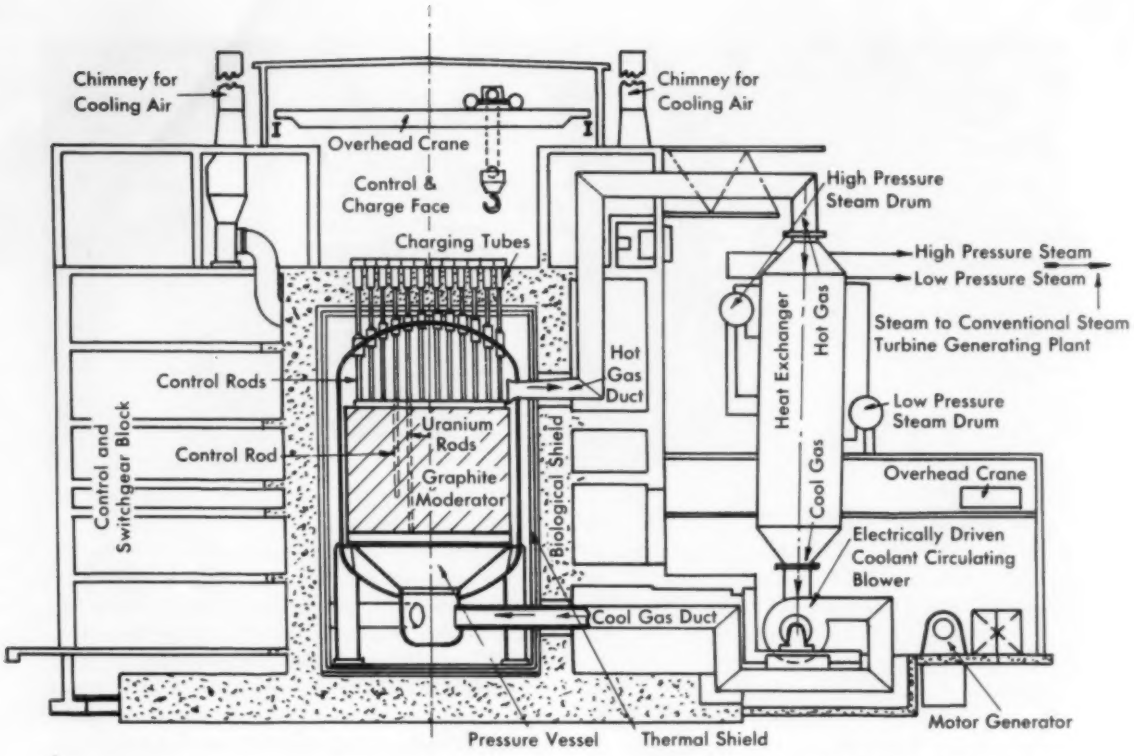

Fig. 6 – Cross Section of a Calder Hall Pile Showing the Pressure Vessel and One of the Heat Exchangers

discontinued because of the difficulty of obtaining a straight bore.

End caps for the cans made of extruded material tended to have stringers of inclusions; to avoid this a method of producing caps by impact extrusion from rolled plate was developed. This produced the required grain flow pattern and eliminated failures caused by inclusions.

"Ratcheting" – distortion of cans caused by mechanical strain during handling and operation or by repeated heating and cooling – is shown in Fig. 5. Severe distortion of an experimental finless can is shown at right and distortion of a finned can, particularly near the end cap, is shown at left. The X-ray in the center shows how repeated heating and cooling has expanded the magnesium can more than the uranium element.

To join the caps to the can, several types of weld were tried, and to protect the weld from ratcheting, the cap was screwed into the can. Thermal cycling tests showed that the threads distorted and could not be relied on to resist this type of load so the design of the end cap was later modified. Automatic methods of argon-arc welding were developed. In the Harwell designs the can was rotated and the distance of the gap was adjusted by movement of the electrode. Welding current was applied in the normal manner and after one complete cycle was reduced automatically to prevent crater formation.

No special precautions, except cleanliness and freedom from volatile material, were taken during insertion of the bar in the can; with a clearance of about 0.010 in. between bar and can it was possible to slide the can over the bar with no danger of sticking.

Reactor Pressure Vessel

The pressure vessel (Fig. 6) operates at temperatures above 650° F. with an internal pressure of 7 atm. The selection of steels is governed, however, by the dimensions, which are 37 ft. diameter and 70 ft. high with plates 2 in. thick. Erection on the site is necessary with attendant difficulties of preheating for welding. Inspection of plates and welds by radiographic or other means is essential to minimize danger of crack propagation arising from defects in the steel. A stress-relieving treatment designed to convert elastic into plastic deformation may disclose cracking in areas of tri-axial stressing.

The steel used must be chemically and metallurgically inactive, or compatible, with the coolant gas at reactor temperatures and pressures. Samples of various steels were exposed for five months to carbon dioxide at 750° F. and 8 atm. pressure with varying moisture contents. The oxidation rate for mild steels decreased parabolically with time, a slightly adherent nonflaking scale being formed. Moisture almost doubled the corrosion rate.

From these results and also on the basis of nuclear properties, the majority of mild and low-alloy steels may be used for pressure vessels. Other considerations are also important, namely:

1. The steel should not be susceptible to brittle fracture at temperatures attained during erection or during a shut-down period.
2. Creep may affect alignment of the charging mechanism.
3. The long-term creep-rupture properties of the steel should be sufficient to give an adequate safeguard against fracture at low ductility.
4. The presence of loose scale on steel plates is obviously undesirable.

The "Lowtem" steel selected for the pressure vessel (0.14% C, 1% Mn) is fine grained and has a low brittle transition temperature. Generally, vessels designed to operate at the Calder temperatures are stressed in accordance with B.S.S. 1500 which bases the permitted stress on a proportion of ambient-temperature properties, creep being considered negligible. Since this steel has been widely used, the metallurgical development actually necessary for this aspect of the reactor was not great and work in this field has been done more with an eye to the future.

For the Calder reactors, stress relaxation data for the pressure-vessel steel were considered desirable since, even after stress-relief, points of stress concentration will exist, particularly at supports and pipework connections. Tests were made on material taken from weld metal, heat-affected zone and parent metal. Tests were made at 660 and 750° F. in a standard creep testing machine, each specimen being stressed to give a constant total strain of 0.15%.

Each type of material exhibited a high rate of relaxation in the early stages of the test; this was most evident in the parent metal at both temperatures of testing. The highest remanent stress in all tests was found in the weld metal – approximately 25,000 psi. after 500 hr. at 750° F.

Stress-Relief – The electrical method of stress-relief and that using recirculated combustion gases were alternatives considered. The former had the advantages of better control, a cleaner process and a simpler installation, and was the one finally adopted although it called for a considerable power supply on site.

Two radiant electric heaters controlled from outside the biological shield were installed within the vessel. These heaters were made up of lengths of thin-walled 18-8 stainless steel tube, 2 in. OD, the heat being generated by the current flowing through the tube wall. The dimensions of the tubing were arranged to give a maximum surface temperature of 1470° F. The emissivity was between 0.55 and 0.8. The tubing was arranged in a number of vertical lengths round the side of the shell, roughly following its contour and about 3½ ft. from it. It was supported from hangers attached to the upper part of the shell and the underside of the support grid through quartz insulators. There were four vertical runs per phase – 24 in all.

Power and switchgear were available at site for an electrical input of 15,000 kw. Two heaters were used, main and subsidiary, to reduce the heavy starting current. The procedure was to use the main higher-rated heater to raise the temperature of the vessel, together with that of the subsidiary heater, to about 640° F., at which point the subsidiary heater was switched on. The initial current to the main heater was 50% in excess of that at 640° F. With the two heaters on at 640° F. the combined current was just within the allowance figure of 2080 amp.

The temperature pattern of the vessel was obtained from more than 100 chromel-alumel thermocouples. Of these a representative 16 were connected to a recorder at the main control station while the remainder were connected to indicators. The temperature of the actual heating tubes was measured as 1350° F. by optical pyrometer, through windows in the outlet branches.

The heat exchanger was stress-relieved by induction heating via long cables.

In conclusion, a vast amount of metallurgical research lies behind the building of Calder Hall, and research is still being vigorously carried on. It is realized only too well that we are but on the threshold of atomic energy developments – what is being done today will look as clumsy and as costly a hundred years hence as one of Watt's early steam engines now looks to us, but the door has been opened to similar important advances in power-plant engineering.

Effects of Radiation on Materials

*Reported by JULIUS J. HARWOOD**

Changes in metallic properties by extreme radiation by neutrons and gamma rays are explainable by displacement of atoms in the crystalline lattice or introduction of new atoms (either fission products or transformed elements). Certain new organic substances of quasi-crystallinity have been produced by intense radiation. (P general, Q general, M25, 2-17)

THE subject of radiation effects on materials is one which all metallurgical engineers will find cropping up more frequently. It will, within a relatively short time, undoubtedly appear as part of the graduate curriculum in many academic centers. As the civilian usage of nuclear power expands, so will the necessity for practicing metallurgists to become more familiar with this fascinating subject – which indeed it is.

A start in this direction was made at the Colloquium on "The Effects of Radiation on Materials", sponsored by the Office of Naval Research jointly with the Glenn L. Martin Co. at Johns Hopkins University in Baltimore late in March.† Its purpose was to present a series of unclassified reviews, educational in nature, broadly covering the field, and so designed as to appeal to both research scientists and engineers working on radiation effects and on the development and design of nuclear power reactors. Some 600 men registered during the three-day course. Industry, government and universities were all well represented. One could almost conclude that, in view of the large attendance at these specialized conferences and symposia, they are becoming an accepted mode of transmitting scientific and engineering information. "Soaking up" a flood of concentrated information in a few days appears to be a popular substitute for the arduous task of keeping up with current literature.

Metals, alloys, inorganic dielectrics, semiconductors, organic and polymeric materials, and materials for nuclear components (including fuel elements, moderators, coolants and shielding materials) were discussed by the speakers. Theories and concepts of radiation effects, sources and measurements of radiation, and the known effects of radiation on the physical, metallurgical, mechanical, corrosion, and electrical properties were presented.

Radiation effects have been more popularly known as "radiation damage" – which is a somewhat misleading term since significant damage often does not occur. More to the point, in some organic materials beneficial changes may result. The experimental approach to this field of research now is undergoing a transition. In the years immediately following 1942 most of the emphasis was concentrated on the determination of the damaging effects of radiation on reactor materials, both fuel and structural. Today there is an equal interest in the use of radiation as a tool for increasing our understanding of the physics of solids.

Radiation Sources and Dosimetry was discussed by J. C. Wilson of the Oak Ridge National Laboratory. The most important source is, of course, the nuclear pile or reactor, and the principal environment of interest is a flood of neutrons having a spectrum of energy levels, plus an intense concentration of very penetrating gamma rays. Fission products traveling at high speed may also be involved. Testing in

*Head, Metallurgy Branch, Office of Naval Research, Washington, D.C. The opinions expressed are those of the author and do not reflect the official views of the Navy Department nor the Office of Naval Research.

†The proceedings will be compiled into a monograph and published by late summer or early fall. Individual papers are not available for distribution.

a reactor is difficult and expensive; the cost of a test series can easily reach $100,000. The working space is limited; shielding, handling and instrumentation problems are complicated; there is also the important problem of removing the heat produced by gamma radiation. Finally the "flux" to which the specimen is exposed is poorly known and controlled; only in a few test holes in the available reactors has the neutron energy spectrum been accurately measured.

Other useful sources of radiation include gamma rays from cobalt-60 or other radio-isotopes, and accelerators such as cyclotrons in which specimens can be bombarded with alpha particles, protons, electrons, deuterons or other charged particles. The latter sources have not been widely used for metallurgical studies, and more and more reactor facilities are becoming increasingly available, both in A.E.C. installations and universities and research institutes.*

In his review of "Defects in Solids, and Current Concepts of Radiation Effects", G. J. Dienes of Brookhaven National Laboratory pointed out that our understanding of radiation effects is still quite imperfect (no pun intended) and theories are being revised continuously. The three main effects of particle bombardment are (*a*) electron excitation, which results in ionization effects that are of primary importance in insulators and organic materials, (*b*) displacement of atoms from their normal lattice position; such collisions form vacant lattice sites and shove atoms over into interstitial positions, and (*c*) thermal agitation of atoms without displacement, due to collisions, which may result in localized rapid heating and quenching – a "thermal spike".

Apparently a bombarding particle must have a threshold energy of about 25 electron volts in order to displace an atom. Resistivity measurements have determined the number of displaced atoms (residual resistivity of materials being extremely sensitive to the number of lattice defects), but experimental results and theoretical calculations are not yet in satisfactory agreement. For metals, the number of displacements deduced from resistivity measurements is less than predicted from theory by a factor of about five; for organics, the factor is about two.

One effect of irradiation is to expand the crystallographic lattice. This results from the formation of interstitials and other lattice defects. Since the recombination of a vacancy and an interstitial atom would annihilate a defect, it follows that at higher temperatures, when diffusion and recombination rates would be higher, this type of damage would be less. Such a hypothesis was nicely substantiated by heating the Brookhaven graphite reactor core at 300° C. (575° F.) for 12 hr. This core had expanded gradually during its operation, and about 30% of the over-all distortion was recovered by the heat treatment, in excellent conformance with the theoretical prediction.

Changes in properties in metals and alloys were discussed by D. S. Billington of Oak Ridge National Laboratory. He noted that changes upon irradiation in electrical conductivity and other physical properties are not significantly great. While changes do occur in mechanical properties, the "damage" is not sufficient to impair the structural and engineering utility of nonfissionable metals. Some engineers will not accept this generalization, but apparently the present reactor designs can tolerate such property changes as do occur. Changes are generally similar to those induced by cold work—hardness, yield strength and tensile strength increase upon irradiation, with the gap between yield strength and tensile strength narrowing. Ductility and related properties decrease and the transition temperature can be substantially increased, even as much as 250° F. in pressure vessel steels. In face-centered cubic metals, such as austenitic stainless steels, neutron radiation causes the appearance of a definite yield point in a stress-strain curve, and this is more pronounced at higher strain rates. Such radiation studies can be expected to improve our understanding of transition temperature and yield point phenomena and the roles played by lattice defects and impurities.

In heavily cold worked samples, radiation may produce effects similar to an annealing heat treatment, indicating that it is not completely analogous to cold work. Indeed, recent studies suggest strongly that the effects of radiation resemble solute hardening more than they resemble cold work, but the magnitude of the property changes is much greater than those produced by solid solution alloying. For solid-state processes in which diffusion is the primary mechanism, radiation is equivalent to an increase in temperature. Thus, precipitation hardening reactions and order-disorder transformations are accelerated by irradiation.

In general, radiation effects are influenced by

*A recent compilation of all reactor facilities in this country is contained in Atomic Energy Commission Report TID-7009.

the temperature of the sample and the flux it endures, as well as prior thermal and mechanical history. In any radiation experiment, particularly in a pile or atomic reactor, accurate interpretation depends upon a thorough knowledge of the specimen's history and careful control of all variables, including the atmosphere. As has been well said, "Assume nothing and measure everything." Pile experiments are too costly and too difficult to warrant a re-run.

The effect of radiation on corrosion and surface reactions was reviewed by M. Simnad of General Atomics. He noted that the results are often difficult to interpret, since both the environment and the metal are affected, and the influence of changes in both the temperature and the surface film must be considered as well as any inherent changes in electrochemical activity. Some recent proton bombardments, wherein changes in electrode potentials and solubility rates were observed, indicated that this should be an interesting and intriguing field of research.

Nonmetallics

While they may be of marginal interest to readers of *Metal Progress*, the changes in electrical properties which result from intense radiation are of great theoretical and practical importance. As pointed out by R. Smoluchowski of Carnegie Institute of Technology, these effects are immediately recovered in metals because of the large excess of electrons which exist in the metallic state. On the other hand, resistivity of the nonmetals is drastically reduced. Since many of our advanced military weapons are so dependent upon electronic guidance and controls, involving accurate functioning of semiconductor and transistor devices, radiation damage is a most serious problem. Under radiation exposure, transistors and semiconductors lose their useful characteristics. Much fundamental work on this problem is under way.

Electron interaction and ionization produced by radiation generally result in severe degradation of organic substances. However, by proper choice of materials and appropriate exposure, completely new polymeric materials can be produced with increased strength, toughness and temperature resistance. Degradation only occurs in "noncrystalline" organic materials. It may be of some surprise to metallurgists to realize that teflon, nylon and polyethylene exhibit degrees of crystallinity – by that term meaning orderly arrangement of polymeric chains. By proper combination of radiation dose and temperature one can produce organic materials of commercial importance with either rubber-like, crystalline, glass-like, or "cheese-like" properties.

Reactor Components

Of greatest interest to reactor engineers are the fissionable metals for cores and fuel elements and the coolants, control rods, moderators, shielding and auxiliary equipment. These subjects were discussed by C. E. Weber of Knolls Atomic Power Laboratory and G. R. Hennig of Argonne National Laboratory. The discussion centered on uranium and the moderator graphite.

If it were not for the fact that the fission of uranium is the basis of atomic energy it would receive little consideration. In fact, the troublesome changes in fissionable materials upon irradiation – self irradiation – lead to the facetious suggestion that it would be highly desirable to build a nuclear reactor without the use of fissionable metals.

For example, uranium exhibits spectacular and undesirable dimensional changes upon irradiation which can markedly affect the operation of a reactor and its efficiency. It grows and swells. This is the result of a number of factors including lattice expansion, due to formation of innumerable "defects", volume changes due to localized allotropic transformation, and the accumulation of fission products – at least two new atoms for every one which splits. The growth of uranium is an exponential function of the amount of "burn-up" (percent fission) and can easily amount to as much as a 30% change in volume.

A most interesting observation has been made recently: Even under extremely low stresses (on the order of 1000 psi.) uranium creeps under exposure to radiation in a pile. When removed from the pile, its normal creep behavior is recovered. This leads to the speculation that materials may be quite ductile under irradiation, even though post-irradiation tests reveal brittleness.

Conclusion – Much remains to be done, both theoretical and practical, on the resistance of materials to radiation. The current state of knowledge about radiation effects is such that, to quote Prof. M. Burton of Notre Dame, "To 'prove' is only to present evidence which demonstrates that the argument is not necessarily incorrect!" Undoubtedly, this is equally valid for recent theoretical developments in most other aspects of the science of metals.

How to Distinguish Brittle From Tough Steel

*By HERMAN GREENBERG**

To insure freedom from brittle failure in service, steel should have a "nil-ductility transition (NDT) temperature" below its minimum working temperature. At temperatures below NDT, samples with a sharp notch break with all-cleavage fracture. (Q23r, Q26s, 1-4; ST)

BRITTLE FAILURES in steel structures were not unknown before the many failures of all-welded ships of World War II vintage. As pointed out by M. E. Shank in *Metal Progress* in September 1954, history records more than 70 other failures of bridges, pressure vessels, storage tanks and other steel structures dating as far back as 1879. The troubles with welded ships warranted intensive investigation by the National Bureau of Standards, the Naval Research Laboratory and other agencies. These established the fact that three conditions are necessary and sufficient for brittle fracture:

1. A stress-raiser, resulting from design or fabrication.

2. A stress sufficiently great to cause localized yielding in the vicinity of the stress-raiser.

3. A service temperature below the ductile-to-brittle transition temperature of the material with the given stress-raiser.

When all three conditions are present a brittle fracture occurs; when one or more conditions are absent brittle fractures do not occur.

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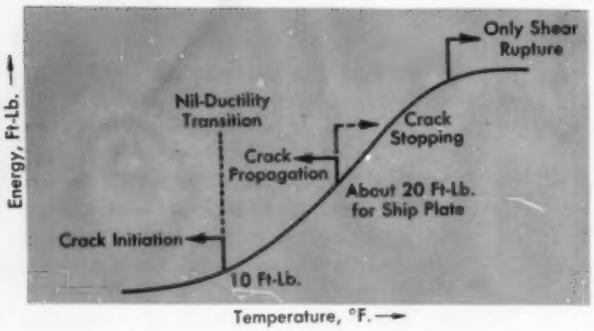


*Fig. 1 – Significance of Charpy Impact Versus Temperature Relationships for Ship Plate Steels (Pellini)**

1. A "nil-ductility transition" temperature – that is, a temperature below which very little pre-fracture deformation occurs and above which considerable plastic deformation precedes fracture.

2. A "fracture transition" – that is, a temperature below which the fracture occurs entirely by cleavage and above which some shearing occurs.

3. A "second fracture transition" – that is, a temperature above which the fracture is entirely by shear.

So much for unnotched specimens. The presence of a notch raises these three

Fig. 2 – Specimen for Drop Weight Test

Obviously a brittle metal – one with a high ductile-to-brittle transition temperature – is undesirable for imporant machines and structures. But how is this to be determined prior to fabrication?

To determine the answer to this question we included, in an extensive investigation started early in 1955 at Westinghouse Electric Corp.'s materials engineering department, a study of the various laboratory tests which have been proposed and used to a considerable extent. These will now be briefly described.

Notched Tensile – If a "ductile" metal such as low-carbon steel is broken in tension at a series of temperatures it will be found that far below zero the fracture occurs by cleavage without appreciable plastic deformation. As the testing temperature is increased, more and more plastic deformation precedes the fracture, but it is still of the cleavage type. With an additional increase in testing temperature, some shear type of fracture becomes apparent around the periphery of the sample ("cup and cone"). Finally, a temperature is reached at which the sample fails entirely by shear. It is thus apparent that steel actually has three transition temperatures, namely:

transitions to higher temperatures. Furthermore, the sharper the notch, the higher will be the transition temperatures. The potent effect of notches is such that all tests for brittle behavior use samples into which a carefully shaped notch is cut, or on which is welded a very hard metal with nearly zero ductility and which cracks in the early stages of the test at very low strain. Furthermore it is apparent that the dimensions of the test piece have a great deal to do with the results.

Charpy Impact – This test has been so widely used that description is unnecessary. When tests are made on steels at a series of temperatures the energy absorbed at low temperatures is low and at high temperatures is high. Sometimes the transition is fairly abrupt, but often it is gradual, as shown by Pellini's generalization for impact strength of ship plate steels (Fig. 1). In such an event the fracture of the broken specimens is taken into account; one can then often determine the point where the cleavage fracture shows the first evidence of shear; the tempera-

*Fig. 1, 2, 3 and 4 are taken from Naval Research Laboratory Report 454, June 22, 1955, and from *Welding Journal Research Supplement*, September 1953.

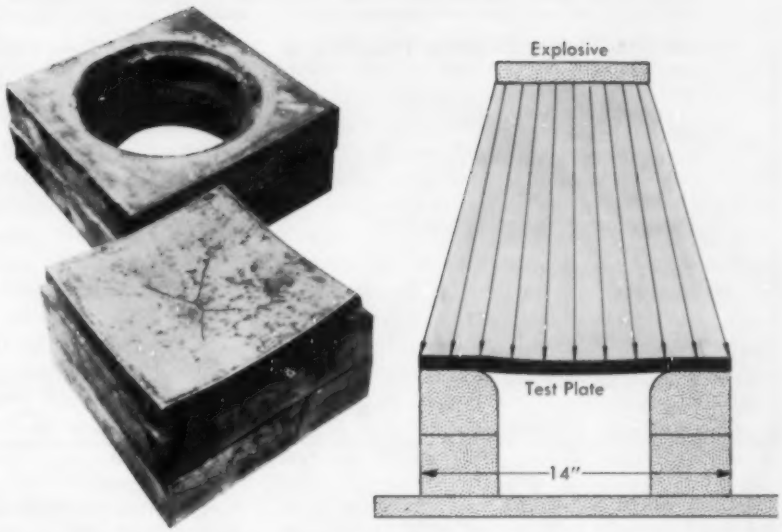


Fig. 3 – Pellini's Explosion Bulge Test for Resistance to Fracture Propagation. Top left is the die for supporting the 14-in. square plate; bottom left is plate after testing at temperature above the "fracture transition"

ture where the fracture is half bright and faceted (cleavage) and half silky and fibrous (shear); and finally the temperature where there is no evidence of cleavage – nothing but shear rupture. The last-mentioned conforms to the definition already given for "second fracture transition". Thus it becomes apparent that the results of Charpy impact tests, expressed merely as ft-lb. of energy absorbed, cannot be used to define transition temperatures without additional corroborating tests.

Drop Weight Test – W. S. Pellini, P. P. Puzak and associates at the Naval Research Laboratory, in their investigations of the brittle fracture of ships, developed a test to measure susceptibility to *initiation* of brittle fracture (the drop weight test) and another to determine the susceptibility to *propagation* of brittle fracture (the explosion bulge test). These are described in Naval Research Laboratory Report 454 dated June 22, 1955.

The drop weight test specimen is shown in Fig. 2. The crack inducer is a bead of hard-facing metal, 3 in. long. It is placed, weld down, on rounded end supports and struck by a 60-lb. falling weight with sufficient energy to bend the

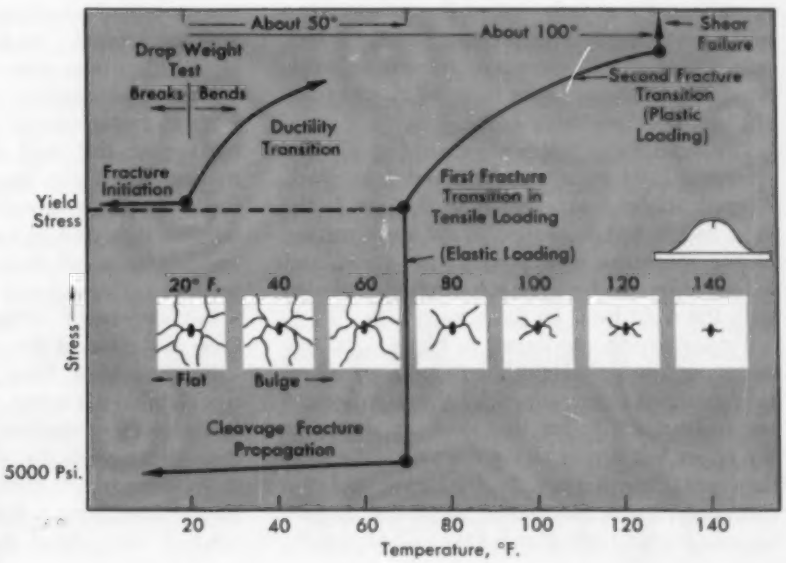


Fig. 4 – Sketches of Plates Tested at Various Temperatures by the Explosion Bulge Test, and Their Relationship to Type of Fracture in Tests on Same Material by Drop Weight and by Tension

Effect of Metallurgical Factors on the Transition Temperature Behavior of Steel Structures

Factors Which Lower Transition Temperatures:	Factors Which Raise Transition Temperatures:
Deoxidation practice	Rimming nature (not deoxidized)
Aluminum residual	High finish rolling temperatures
Silicon (below 0.25%)	Increased section size
Small ferritic grain size	Carbon
Alloy content	Nitrogen
Higher manganese-to-carbon ratio	Oxygen
Low carbon	Phosphorus
Low phosphorus	Boron
Nickel	Molybdenum
Heat treatment	Silicon (over 0.25%)
Normalizing	Annealing
Quench and temper	Notches
	Temper brittleness
	Cold deformation or straining
Chromium Has Little Effect	

specimen about 5°. A cleavage crack forms in the bead as soon as incipient yield occurs – at about 3° deflection – thus forming the sharpest possible notch, a cleavage crack in the test specimen. A series of specimens are tested over a range of temperatures to find the nil-ductility transition – that is the temperature below which steel, *in the presence of a cleavage crack*, does not deform plastically prior to fracturing, which is to say that fracture occurs immediately on yielding of the steel.

This is actually a "go, no-go" test; either the specimen breaks or it doesn't. It is surprisingly reproducible. For example, Pellini made 82 tests from one plate of semikilled low-carbon steel. At 40° F. all ten specimens remained unbroken. Likewise, at 30° F. all ten specimens refused to break. At 20° F. only one of the 14 specimens broke; however, at a temperature just 10° colder, only one of the 14 specimens refused to break. At all temperatures lower than 10° F. every one of the tested specimens broke.

Explosion bulge test is shown in Fig. 3. The specimen is 14 in. square by about 1 in. thick. A crack starter weld, similar to the one in the drop weight test, is applied to the lower surface of the specimen, it is placed over a die, and is loaded by the force of a controlled explosion with the weld bead on the tension side.

Typical results are shown in Fig. 4. At temperatures lower than the nil-ductility transition temperature as determined by the drop weight test – about 20° F. for this steel, as shown at the upper left corner of the diagram – the steel does not deform prior to fracturing and the specimens break flat under explosive impact because fracture initiation is easy. The fractures also propagate easily through the very lightly loaded edge regions which had been supported by the die. Just above the nil-ductility transition temperature, considerable plastic deformation (bulging) precedes fracture; this means that it is now more difficult to *initiate* a fracture, but propagation is still very easy since fractures run to the edges. As the testing temperature is increased to where fracture is partly by shear, its *propagation* becomes more difficult, and fractures are confined to the area of bulging (forcing); they no longer run through the lightly loaded edge regions. Some shearing is evident along the edges of the fracture. At still higher temperatures, brittle fractures cannot propagate – fractures progress entirely by shear.

From the above it will be appreciated that the concept of transition temperature has become well established. In fact a very large amount of work has been done to relate a desirable low transition temperature with the various metallurgical factors which are encountered in the making of the steel and its fabrication into structures. While "tough" steel is only one of the three things necessary to avoid catastrophic failures, it is well to know what the steelmaker and fabricator can do to avoid trouble with their product. These things – as far as known with a fair degree of certainty – are listed in the table at the top of the page.

Notched Slow Bend Test – There has been considerable difference of opinion as to whether the behavior of steel structures can be predicted from tests such as the above involving very high strain rates which seldom correspond to actual service conditions. A new test known as the notched slow bend test therefore has been

proposed by various men investigating brittle fracture of steel structures.

Test specimens are geometrically similar to the standard Charpy V-notch specimen and may range in size from ⅜ in. square by 2 in. long to 9 in. square by 6 ft. long. For these samples the depth of notch varies from 0.038 in. to 1.8 in. but the notch radius is kept constant for each series of specimens. Samples are bent in a tensile testing machine at very low strain rates with the notch in tension. Load versus deflection measurements are recorded; the load-carrying ability (strength) of the material can be calculated from the breaking load, and the deflection measures relative ductility.

This test has not yet been widely applied. As far as is known to the writer, it has been used primarily for testing at room temperature, and brittle or ductile behavior depends on the *size* of the sample – small pieces will bend whereas large enough bars of the same material will break. It is perhaps unfair to the test to judge its merits at present, but it appears that a large amount of test material and shop expense is required and it would be difficult to maintain temperatures in this relatively slow test. These objections would disappear, of course, if future experience would find that the results of the notched slow bend test can be closely correlated to service performance in complicated structures.

Design Considerations – Only passing mention has been made of the time-honored tensile test. In the past the "ductility" figures (elongation and reduction of area) have been regarded as measures of "toughness", and toughness has been thought of as the ability to absorb overloads by plastic deformation and therefore the antonym of "brittleness". Fairly recently, as time goes, the idea was advanced that these tension tests should be performed at the temperatures to be anticipated in service, and strength and ductility figures secured in this way should rule the design. Recent brittle fracture studies, however, indicate that in many instances, transition temperature may be a more important design consideration than ductility measurements obtained from tensile tests.

An increasingly popular school of design is based on the principle that structures can safely be loaded almost to the yield strength of the material with the supposition that a small amount of plastic yielding will occur in the vicinity of stress-raisers. The applied stresses are then expected to redistribute themselves to adjacent areas which will then safely carry a greater proportion of the load. This is an excellent idea provided the design engineer is certain that the material selected has the ability to deform plastically at all operating temperatures *in the presence of stress-raisers.*

Westinghouse Test Program – In the light of such facts as have been so briefly considered in this article, an organized effort at Westinghouse Electric Corp. has been made to study and appraise the steels commonly used in Westinghouse equipment. All of the various tests for determining transition temperatures were considered and it was decided that emphasis should be placed on the accumulation of test data from Charpy V-notch test bars, supplemented by drop weight tests. This selection is based on the fact that the Pellini drop weight test provides a reliable and reproducible measurement of the nil-ductility transition temperature – that is, the temperature below which it is extremely easy to initiate a brittle fracture and propagate it at a catastrophic rate.

In every case investigated the drop weight test has revealed a nil-ductility transition temperature above the service failure temperature of steels that have failed in service by brittle fracture. This perfect correlation has not been restricted to ship plate failures, but has been extended to the brittle fractures of annealed alloy steel (as in a pressure vessel failure), normalized and tempered alloy steel (as in another pressure vessel failure) and quenched and tempered alloy steel (as in the failure of a large forged ring).

The drop weight test has also correlated well with the Charpy V-notch impact test as shown by the fact that, when testing different lots of steel having the same chemical composition and heat treatment, approximately the same Charpy value (ft-lb. of absorbed energy) is obtained for each lot at its respective nil-ductility transition temperature. This is extremely important because in many metal parts such as rotor forgings, retaining rings and small bar stock, insufficient material is available for conducting the complete drop weight test (ten samples, 14 × 3.5 × ¾ in. thick). Nevertheless we can properly conduct both tests on a scrapped forging or on larger sized bar stock and obtain the Charpy energy level which corresponds to the drop weight nil-ductility transition temperature. It then only becomes necessary to obtain sufficient material for two or three Charpy tests to learn whether a particular forging or bar of steel has a nil-ductility transition temperature higher or lower

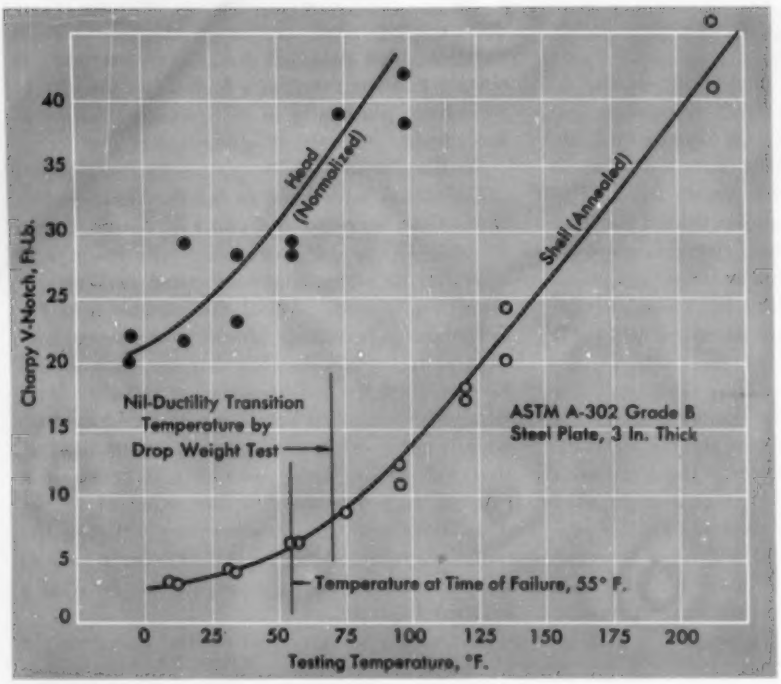


Fig. 5 — Correlation of Charpy V-Notch and Drop Weight Tests for a Pressure Vessel Which Failed in Service at 55° F.

		Shell	Head
Composition:	C	0.17	0.20
	Mn	1.22	1.15
	P	0.026	0.015
	S	0.011	0.021
	Si	0.27	0.30
	Mo	0.47	0.49
	Al	0.05	—
Ultimate		70,100	86,200
Yield (0.2% offset)		37,500	61,200
Elongation in 2 in.		28.9	28.5
Reduction of area		49.6	57.0
Brinell hardness		133	172

than the minimum operating temperature. If enough metal is available for 12 to 15 Charpy specimens, tests can be conducted over a range of temperatures to find the temperature at which Charpy specimens absorb the same amount of energy as those tested at the drop weight nil-ductility transition temperature in the standardized test of material having the same composition and heat treatment. This temperature is the nil-ductility transition temperature of the specific part.

The test program being conducted at Westinghouse is two-fold in nature. First, any available part which fails by brittle fracture will be investigated by drop weight tests to get additional evidence on the correlation between service failure temperature and nil-ductility transition temperature. Second, the drop weight nil-ductility transition temperatures of representative lots of various types of steels will be determined and correlated with Charpy V-notch data on the same material. This information will be used to advise design engineers about the possibility of brittle fracture occurring in the various steels.

From the test data already acquired, Fig. 5 and 6 show the correlation between drop weight tests, Charpy V-notch impact tests and service failure temperatures of material from a pressure vessel (Fig. 5) and a large forged ring (Fig. 6), both of which failed in service by brittle fracture.

Data about the shell and head of the pressure vessel are given in the caption of Fig. 5. The forged ring whose impact versus temperature relationships are shown in Fig. 6 had the following composition: 0.35% C, 0.54% Mn, 0.010% P, 0.025% S, 0.15% Si, 3.39% Ni, 1.08% Cr, 0.01% Mo and 0.03% Al. It was 58 in. outside diameter, 53 in. inside diameter and 16 in. long. It had been quenched and tempered as final heat treatment in such a way as to become "temper embrittled", as shown by the very low Charpy values at 70° F. In this condition tensile tests showed 122,000 psi. ultimate strength, 99,000 psi. yield strength (0.2% offset), 17.7% elonga-

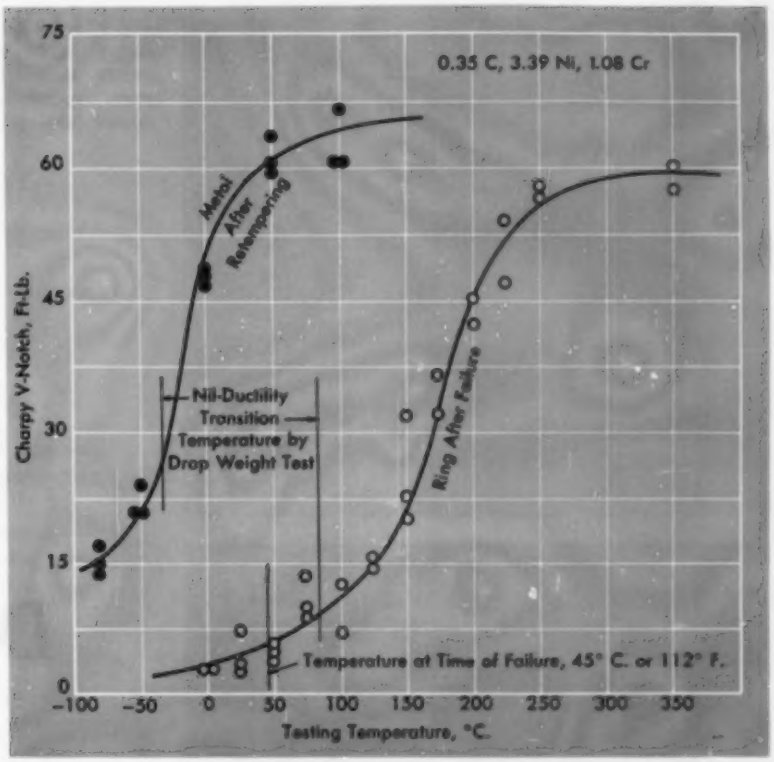


Fig. 6 – Charpy V-Notch Tests at Various Temperatures (and Nil-Ductility Transition Temperature) on Heavy Cr-Ni Steel Ring Which Failed in Service, and Similar Data on Same Metal After Proper Heat Treatment

tion in 2 in., 50.7% reduction of area, and Brinell 268.

Samples cut from the failed ring were subjected to drop weight tests. Two did not break at 200° F., one broke and one did not at 180 and also at 176° F., all broke at temperatures of 166 and lower. The nil-ductility transition was therefore placed at 176° F. or 80° C. in the condition when fracture occurred. (Failure was at 112° F. or 45° C.)

A large piece of the ring was then retempered 2 hr. at 1150° F. and water quenched. Test pieces were then cut and tested by drop weight. None broke at −25° F. and above; all broke at −35° F. and below. The nil-ductility transition was therefore placed at −30° F. or −35° C.

Conclusions

1. Three conditions are necessary and sufficient for brittle failure. These are *(a)* a stress-raiser resulting from design or fabrication, *(b)* a stress sufficiently great to cause localized yielding in the vicinity of the stress-raiser, and *(c)* a service temperature below the ductile-to-brittle transition temperature of the material.

2. When all three conditions are present, a brittle fracture occurs. When one or more conditions are absent, brittle fractures do not occur.

3. Although the term "transition temperature" has been defined many different ways by various investigators, steel actually has three transition temperatures. The most important of these is the nil-ductility transition temperature below which fracture easily starts and propagates.

4. The Charpy V-notch test and the drop weight test show good correlation with service failure temperatures.

5. The notched slow bend test has not been studied sufficiently to be useful in an investigation of transition temperatures.

6. The drop weight test provides a reliable and reproducible measurement of the nil-ductility transition temperature.

7. In some instances, transition temperature may be a more important consideration for designers than ductility measurements obtained from tensile tests.

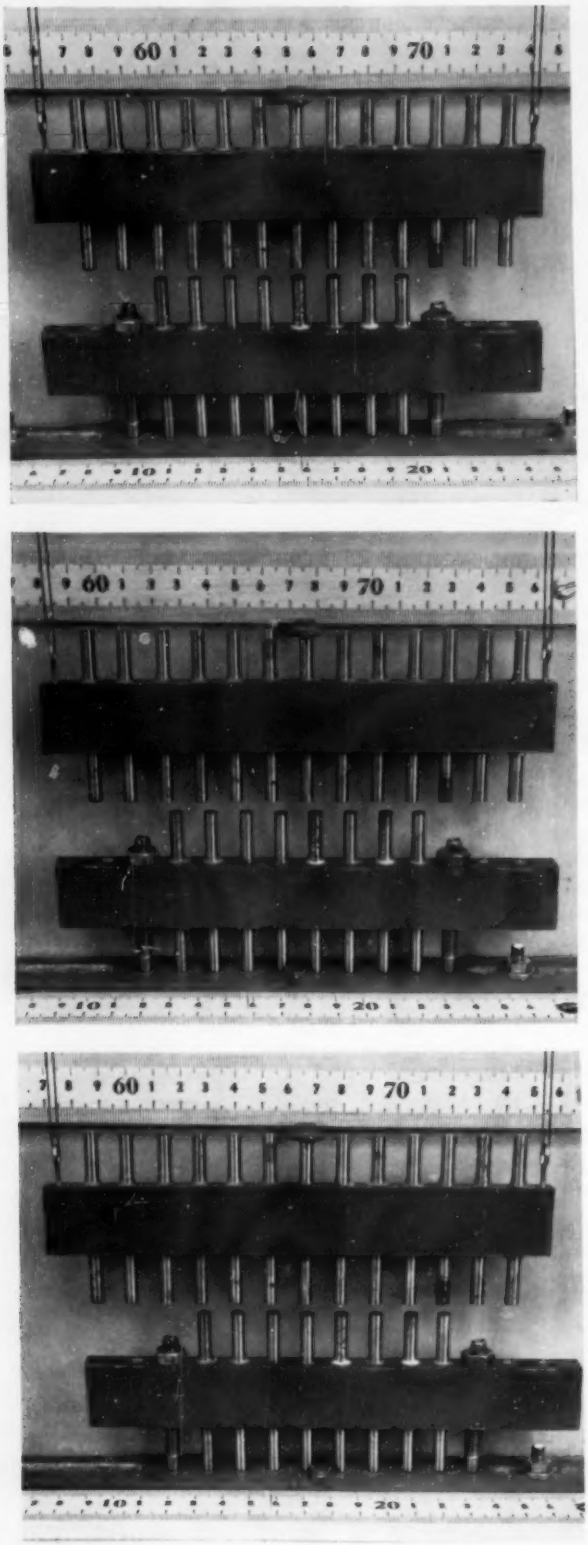


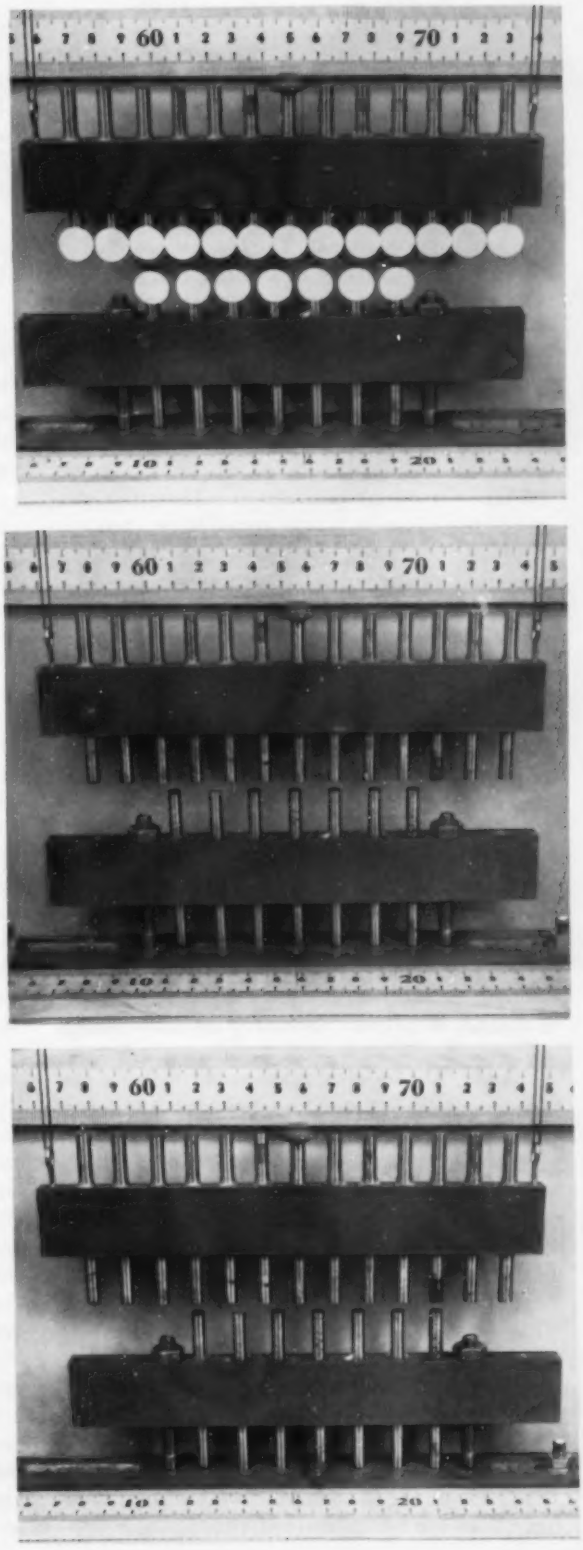
Fig. 1 – Model Illustrating Slip in Perfect Crystal. Top represents equilibrium before stressing; middle represents maximum elastic displacements; bottom is equilibrium after slip of one atom diameter

Magnetic Analogy of a Dislocation

"METALS ARE WEAK because of dislocations." This concept was historically the foundation of the dislocation theory proposed by G. I. Taylor in 1934, and it has since been widely used in the present diversified theory. (See, for example, "Dislocations, or What Makes Metals so Weak", by W. T. Read, *Metal Progress*, February, 1954, p. 101.) A need was felt for a convincing demonstration of this relationship between strength and dislocations when teaching metallurgy students – a need that was not satisfied by soap-bubble rafts or models involving hard spheres. A model utilizing magnets appeared to be a likely possibility, and the sophomore students in metallurgical engineering at Purdue University constructed a gadget with carbon steel magnets that demonstrated the feasibility of this approach. A somewhat refined magnetic model illustrating atomic interactions is described here.

The purpose of the model is to illustrate the interaction of a row of "perfectly" spaced atoms with *(a)* either another similar row of atoms, *(b)* a row of atoms containing a "dislocation", or *(c)* a single atom. The

Fig. 2 – Model Similar to Fig. 1 Except That Bottom Row of Atoms Represents Crystal With Dislocation. Set at top has cardboard disks denoting atoms and to increase visibility in classroom.



*By A. G. GUY and L. G. CRISWELL**

Two rows of equally spaced magnets, the upper one swung like a pendulum, form a physical model which illustrates that the force necessary to cause slip in a perfect crystal is much greater than in a crystal containing dislocations.
M26b, Q24a, 17-6)

"atoms" are represented by the ends of long magnets. For classroom demonstration, Case *(b)*, the actions are made more graphic by attaching small cardboard circles, representing atoms, to the end of each magnet.

In both sets of photographs on these pages the upper row represents the perfect spacing. The lower row in Fig. 1 is spaced exactly the same, but the lower row in Fig. 2 contains a "dislocation" – seven atoms (magnets) occupy the space corresponding to the eight atoms having perfect spacing.

By aligning all the magnets in the top row with the north pole facing down, and all those in the bottom row with south pole facing up, forces of attraction are exerted between the two rows of "atoms". These forces attempt to maintain the two rows in some equilibrium position and act

*Dr. Guy is professor of metallurgical engineering and Mr. Criswell is an undergraduate in chemical engineering at Purdue University, Lafayette, Ind. The advice of Prof. F. J. Friedlaender on magnetic effects and the help of H. S. Herron with the building of the model are gratefully acknowledged.

against any external force tending to cause movement (slip) of one row past the other.

Now, since a dislocation makes a metal weak by making slipping easier, it is desirable to show that the external force required to move a dislocated row of atoms from one equilibrium position to the next is smaller than that required for a normal row of atoms. The force measurements involved can be made in a number of ways, but it is very convenient to use gravity as the restoring force in a string suspension. When the top magnet assembly is suspended by long strings, it can be shown that the force tending to restore it to the "free hang" position is directly proportional to the displacement from this position, provided the displacements are small (as will be true for a long pendulum). Thus, to determine the relative forces required to produce slipping, one need determine only the corresponding relative displacements.

Figures 1 and 2 show how such a magnetic model can demonstrate the reduction in the force necessary to cause slipping when a dislocation is present. The three photographs of Fig. 1 illustrate the process of slip in a "perfect" metal. At the top is the unstressed, equilibrium position of the two rows of atoms. The middle view shows the largest relative displacement that occurs in the "elastic" range, that is, before slipping occurs. Note that the marker at the center of the lower row has been moved from 150, its original position against the scale, to 175, a distance of 25 mm. Simultaneously, the upper row of magnets has been swung from its original position of 653 toward the left to 675, a distance of 22 mm. As the top assembly swings to the right, in attempting to follow the bottom assembly, it generates an opposing force in the string suspension equal to the shearing force, corresponding to the measured displacement of 22 mm. The bottom view shows the new relative position of the two rows after "slip" has occurred. The lower assembly has been moved from 150, its original position, to 177, a distance of 27 mm., while the upper assembly has swung back from 675 in the middle view to 666, a distance of 9 mm., thus partially relieving the applied force.

Figure 2 shows a similar sequence when the bottom row of atoms is not "perfect" but contains a "dislocation". The top view shows equilibrium, and disks have been attached to simulate atoms. It is seen in Fig. 2, middle, that the maximum force than can be applied before slipping occurs corresponds to only 6 mm. (65.0 initially on top scale; 65.6 in the middle view) rather than the 22 mm. required in Fig. 1 for a perfect "crystal". Figure 2, bottom, shows the position similar to Fig. 2, top, except that the dislocation has moved one atom spacing to the right. The lower row of atoms has at this time moved 21 mm. to the left and the suspended set has moved 7 mm. to the left.

An interesting feature of Fig. 1 is the fact that the maximum "elastic" displacement of the bottom row past the top row is only 3 mm., a small fraction of the intermagnet spacing, 13 mm. One might, on first thought, expect that this displacement would be *half* of the intermagnet spacing. However, a convincing demonstration that the facts are otherwise can be made using a single magnet in the lower position. One can then obtain data on the variation of the force on *one* "atom" as its position is varied relative to an adjacent *row* of atoms. These data suggest a sinusoidal variation of force with displacement. A rough calculation based on point magnets supports this result. The calculated curve shows a maximum force near 20% displacement, a decrease to zero at 50% displacement, and then a change in sign of the force for the balance of the displacement.

One is tempted to consider how the present qualitative model might be changed into a quantitative one. First, there is the complex problem of devising a better approximation to the actual interatomic forces than afforded by the single row of magnets. Also, it would be desirable to create a more realistic dislocation than the rigid array used here. A model that would operate in two dimensions or in three dimensions is also an attractive possibility.

A few notes on the construction of the model may be of interest. The alnico magnets, 3/16 in. in diameter and 2.5 in. long, were obtained through the courtesy of John Fisher of the General Electric Research Laboratories. They were magnetized in a field of 10^5 ampere-turns per m. and were tested for uniformity by deflection of a compass needle. (These distances varied within the range of plus or minus 5%.) The magnets were glued at 0.5-in. spacings on bakelite strips. The clearance between upper and lower rows is about 0.15 in. A greater number of magnets was used in the top than in the bottom row to minimize end effects. At least three extra magnets at each end should be used for this purpose.

The First Ferro-Uranium Made in America

*By CLARENCE T. PATTERSON**

Uranium oxide byproduct from radium refining was first smelted in an Acheson type of resistance furnace. Commercial alloy was later produced for toolsteel makers in a small carbon arc furnace, lined with sintered U_3O_8, by first forming a carbide from an oxide-coke mix, distilling off the carbon, and then dissolving boiler plate punchings in the molten uranium. (C21d, A2; U, AD-n)

URANIUM IS a metal which has been in the public prints for more than a decade, ranging from highly scientific publications to highly imaginative ones, including the daily press. This has, of course, been based on the pure metal, the starting point for all sorts of atomic weapons and resulting international tensions, a new power source with inestimable reserves, radiation both benign and lethal, and new scientific methods of great precision and delicacy. All this has grown up with amazing speed – the scientific part, in fact, since January 1939 when atomic fission was discovered, and the public discussion since the middle of 1945 when President Truman announced the bombing of two Japanese cities. In the early 1940's the production of metal grew rapidly from gram quantities for physical and chemical experiments to tonnage for the explosive plants.

Practically forgotten is the fact that in 1914, just at the beginning of World War I in Europe, some experimentation started on the use of uranium as an alloying element in toolsteel – hopefully as a substitute for the then-scarce tungsten – and resulted in the commercial production of ferro-uranium. I wish to place on record an account of this early effort.

In September 1914 I interviewed J. M. Flannery, then president of the Standard Chemical Co. of Pittsburgh, to get a suggestion for a research project for my senior thesis in metallurgical engineering at Carnegie Institute of Technology. I proposed a study of electric furnace reduction to replace the thermit reaction in producing ferrovanadium, but he told me that the electric process was already in operation. However, as a byproduct of radium production he had then accumulated a large pile of uranium oxide for which there was only a very small market, and he had seen an advertisement a couple of months before in a British engineering journal wherein a German firm was offering ferro-uranium for sale. It was said to be an alloy for improving steel. He promptly sent for a sample but the sudden outbreak of war in Europe prevented its delivery. Nothing was known about the German method of manufacture, so it was his opinion that a study of ferro-uranium would make a good thesis. He offered me as much uranium oxide as I could use, provided I gave him a copy of the thesis. The agreement was kept.

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Preliminary Search

The first thing to do was to search the available literature. This revealed that, up to 1914, very little seemingly was known about uranium metal. No uranium alloy systems had been described. The French Government in 1897 had experimented with uranium in an attempt to improve gun barrel steel but results were secret. In 1911 a German patent was granted to Electric Furnaces & Smelters, Ltd., for fusion in an electric furnace of a mixture of uranium carbide plus oxides and ferrosilicon. An article by C. L. Parsons in *Metallurgical & Chemical Engineering* (the predecessor of *Chemical Engineering*), Vol. 11, 1913, p. 275, said there had been no uranium metal produced in the United States, although some $14,000 worth of oxide had been shipped abroad and refined uranium salts were imported for chemical uses.

This search revealed a wide open field with two clues to indicate probable success. Furthermore, uranium had been placed by the chemists in the periodic table under molybdenum and tungsten, hence a great deal of similarity to these metals was to be expected.

Two methods were considered worth trying: First, the Acheson type of resistance furnace used for conversion of carbon into graphite would be tried because it could generate a very high finishing temperature if conditions were correct. The actual temperature required for reduction of the oxide with carbon was quite uncertain.

Second, the Girod type of single arc furnace would be tried. At the focus this necessarily operates at arc temperature, although the molten mass below may be at a lower temperature.

Carbon was considered the most promising reducing agent in both, since it was the cheapest available, its oxide goes off as a gas, and at that time it was almost the universal reducing agent for metallic oxides. There would be no slag to interfere with recovery of ferro-uranium. Excess carbon in the metal was to be avoided by providing a little excess uranium oxide in the charge.

We will see that this idea needed considerable modification!

The First Furnace

In October 1914 I constructed my first furnace for this work. It was built of standard firebrick as shown in the photograph opposite (not too good originally and somewhat faded with age). The cavity for the charge was to be 4½ in. deep, 8½ in. wide, 63 in. long. For this a floor pad 85½ by 31½ in. was made by laying bricks flat without mortar. Joints were staggered. Two such layers required 133 bricks. Two graphite electrodes 2¼ by 2¼ by 30 in. were then laid on this bed, each with one end across the end of the charge space and the other ends projecting through opposite sidewalls. On the floor pad the side and endwalls were then laid up, two flat bricks wide and four high, with close-fitting staggered joints and no mortar. This required 167 more bricks. All outer joints were then luted with fireclay. The charge cavity was then finished to 8½ in. wide by laying sidewise seven bricks against each sidewall between the electrodes. The volume of the cavity was about 2400 cu.in. It could be covered by laying 14 bricks across the top.

Four broken graphite electrodes 1½ in. diameter were laid along the centerline of the cavity making firm contact with the end electrodes yet leaving a 12-in. gap at the center. One or more of these auxiliary electrodes could later be moved to lengthen or shorten the gap as desired.

Electric power available for this furnace was 100-kw., 60-cycle, alternating current. Voltage was selective from 5 to 110, but current was limited to 1000 amp.

The first furnace charge consisted of 100 lb. of uranium oxide powder, U_3O_8, 12 lb. of coke lumps ¼ to ½ in. in size, and 50 lb. of short wrought iron bars, ½ in. diameter, 3 in. long. Five of the iron bars were laid in loose contact between the ends of the auxiliary electrodes for easy starting. The remainder of the charge was mixed and packed even with the top of the inner row of bricks, from the middle nearly to the ends of the charge cavity. Bricks laid across the charge completed the arrangements.

Power was turned on in graduated voltage steps, up and down, to build the current up to 1000 amp. and hold it there as long as possible. The first sparking and arcing was followed by progressive fusing and a fuming reaction which slowly spread. As the molten pool spread the voltage was reduced to keep the current under 1000 amp. From time to time power was cut off long enough to move or take out a short section of auxiliary electrode, and a new start was made with voltage control as before. After about two hours' operation most of the charge had reacted and some of the firebrick lining had slagged into the melt.

First Ferro-Uranium Furnace in America; 1914

This concluded the first test. The furnace was allowed to cool undisturbed overnight.

Next day the fused mass was dug out. It was mostly slag loaded with bright hard pellets of metal unlike the original wrought iron. The pellets, about ⅜ in. diameter, were sturdy enough to resist hammering on an anvil to clean off the slag. Then harder blows cracked them into several pieces. Fractures were rated as "tough-crystalline". A sample was sent to the Standard Chemical Co. for analysis, and the report was 7.14% uranium, 3% carbon.

This was the first ferro-uranium made in the United States.

Since a richer alloy, say 40% uranium, was desired for commercial use in steelmaking, the furnace was repaired and three more trials were made with variations in the charge designed to increase the uranium-iron ratio. These indicated that the Acheson type of furnace was not a practical way to make a large amount of ferro-uranium at a reasonable price.

The Single Arc Furnace

The next furnace was built in the following manner: A floor pad, 27 by 31½ in., three layers high, was made of firebrick close fitted without mortar. This required 63 bricks. A graphite electrode 2 by 2 by 24 in. was laid on the long centerline so that 6 in. overhung the pad. For the charge space in the center, four bricks laid sidewise formed a cavity over the end of the electrode, 4½ by 9 in. Then four more bricks made it 9 in. deep. The walls around this were made two flat-bricks wide and five courses high. This required 90 more bricks. These were laid without mortar; then all outside joints were luted with fireclay.

Electric power available was the same source used for the first furnace. The charge for this furnace was 50 lb. of uranium oxide powder, U_3O_8, 7 lb. of coke fines less than ¼-in. size, and 25 lb. of short wrought iron bars, ½ in. diameter and 1½ in. long.

An arc was struck at 60 volts between the bottom electrode and a vertical one, the latter having been arranged for hand adjustment above the center of the cavity. The mixed charge was fed in slowly as melting and reaction proceeded. Control of the current was quite erratic under these conditions — and so were the reaction products! No uniform melt was obtained, but a study of the results of several trials indicated that, on a larger scale and with better electrical control, this method should produce ferro-uranium commercially.

Early Uses

These experiments were reported in my senior thesis and a copy given to the Standard Chemical Co. in June 1915. This company soon began producing ferro-uranium by its own modifications of the direct arc method. Some silicon was added to aid oxide reduction; lime and fluorspar were added to thin the slags. Typical analyses of their products came within the following limits: 37 to 45% uranium, 3.5 to 5% carbon, 2 to 3% silicon.

This alloy was used to replace a considerable amount of tungsten in high speed toolsteel. Some very good results were reported. One was with a brand trade-named "Electrite Uranium High Speed", made by Latrobe Electric Steel Co. Also some inconsistently poor results were reported by Crucible Steel Co. It became apparent that high carbon and high silicon in the ferro-uranium were causing these elements to get out of desired limits in steelmaking. Attempts to oxidize the carbon usually lost more uranium metal to the slag. Still worse – sometimes the heavy uranium oxide remained suspended in the steel where it could do harm yet appear as uranium in the chemical analysis.

(When I returned to uranium research two years after graduation, I showed that distribution of uranium could be revealed by its own radioactivity. A section of the steel placed on a photographic film in a darkroom would in time cause darkening in the developed film. Irregular or spotty film tells its own story.)

In April 1917, H. W. Gillett and E. L. Mack of the U.S. Bureau of Mines discussed the ferro-uranium situation. They reported on making ferro-alloys containing 40 to 70% uranium and less than 2% C, under 0.75% Si, negligible Al, S, P and Mn. They used fluorspar slag formers in a direct arc tilting furnace with magnesite lining built into a water-cooled steel shell.

Commercial Production

From March through June 1917 I made "Electrite Uranium High Speed" and other toolsteels at Latrode Electric Steel Co. and I learned first hand about the problems of getting the required amount of uranium in the steel in useful form, and the aggravation of high carbon and silicon in the alloys. The alloy price at the time was $7 per lb. of uranium.

In July 1917 I started working for Mr. Flannery at his plant, the Standard Chemical Co. in Cannonsburg, Pa., on a research program which in time resulted in the regular production of 40% ferro-uranium with 0.5% C max., 0.1% Si max., all other elements negligible.

The final successful furnace had a single arc, and a tilting shell lined with uranium oxide. It was not a very big furnace; the steel shell was only 16 in. in diameter and 24 in. deep. Trunions were at mid-height. The bottom electrode was a replaceable steel bar, 3 in. in diameter, projecting about 2 in. into the furnace and 6 in. below the center of the bottom. The shell was cooled with compressed air blasts when necessary. The top electrode was a 5-in. diameter carbon. Power available was 150 kw., 60 cycle; 3000 amp. current was available at maximum load.

Lining – Powdered uranium oxide, U_3O_8, was bonded with a mixture of tar and kerosene to a consistency which would ram like molding sand. First, a 6-in. layer was rammed on the bottom. Then a removable wooden core, 18 in. high and conical shape (8-in. top and 6-in. bottom diameter) was set and the sides rammed hard. After the core was removed a long nail was driven down through the hearth to the bottom electrode to aid in starting.

The cavity was filled with coke of ¼-in. size, the top electrode set down on the coke, and power turned on. For about half an hour only a small current flowed, accompanied by much sparking in the mass of coke; during this time the kerosene distilled and burned above the lining. When most of the kerosene was gone the coke temperature and conductivity rose rapidly, so the top elelctrode was raised by a hand-operated worm wheel to maintain an arc near the full electric load. The incandescent coke slowly vaporized or oxidized and the ambient air burned the carbon monoxide. In about an hour the working chamber was practically empty and slightly enlarged. Its inner surface was glazed with what was assumed to be U_2O as long as it was protected with carbon vapor, and with a higher oxide when exposed to air.

Into such a cavity the following charge was fed slowly: 50 lb. of uranium oxide powder, U_3O_8, and 15 lb. of petroleum coke, ¼ in. size. This charge entered the arc; when reduction was complete a pool of liquid was observed which from previous experience was assumed to be molten uranium carbide, UC_2. Continued application of full arc power caused the liquid to boil, and two vapor layers were seemingly produced as long as any carbon was left in the boiling metal bath. The arc could be seen playing down through the layer of carbon vapor and disappearing at the top of the uranium vapor some distance above the pool of metal.

The layer of carbon vapor was quite variable due to the fast reaction with air around the electrode. On the other hand, the level of the uranium vapor was fairly stable and varied slowly from 3 to 5 in. above the boiling liquid. Little drops of liquid metal were seen coalescing on that part of the walls of the working chamber which was protected by uranium vapor and the

larger drops trickled down into the bath.

When practically all of the carbon had boiled out the sound of the arc suddenly changed. This was a warning. When ambient air touched the uranium vapor the layer collapsed and the arc went out. Immediately 30 lb. of warm steel boiler plate punchings was dropped into the pool of boiling metal, and steel dissolved like ice flakes in hot coffee. The electrode had by this time been raised out of the way so that the furnace could be slowly oscillated while another 30 lb. of steel was added and dissolved. This brought the temperature of the liquid near enough to its freezing point so it could at once be poured into a cast iron mold, ganister lined.

The ingot usually weighed about 100 lb. and met the specification of 40 to 42% uranium, 0.50% carbon max., 0.14% min. These ingots were broken to lump size in a large jaw crusher. This low-carbon alloy was mildly pyrophoric; therefore it was usually shipped in metal cans or small wooden kegs. The price was once quoted at $25 per lb. of contained uranium.

The above details of the operational procedure were developed after many trials and failures. Once the furnace was tilted to pour out pure uranium – but before the liquid got out it took fire, turned to a sludge and stuck on the wall. The furnace lining was repaired when needed by burning on a patch in the same manner as when making a new lining. Attempts to boil carbon out of high-carbon ferro failed, for the alloy cut through the bottom.

Experimental Uranium Structural Steels

The new low-carbon Fe-U alloy was tried out for new toolsteels and in the much larger market of low-alloy structural steels. In standard openhearth practice nearly all the uranium was oxidized into the slag and such an expensive "scavenger" could not be profitable. After several trials in customers' electric steel furnaces, the Standard Chemical Co. built its own half-ton basic-lined electric steel furnace.

Experiments run in this furnace indicated that, in order to get all the uranium into the steel, it was necessary to deoxidize with fine coke until the slag gave a good test for calcium carbide. Ferro-uranium put in the furnace and worked through this slag was all taken into the metal bath. One of the best steels made this way analyzed 0.40% C, 2% Ni, 1.40% U, 0.65% Mn, 0.25% Si, 0.02% S, 0.01% P. This steel was cast, reheated, forged, annealed and machined without difficulty – in fact much like a similar nickel steel without uranium. However, after heat treatment and a water quench, a standard tensile test piece gave this remarkable result:

Tensile yield	274,000 psi.
Ultimate strength	330,000 psi.
Elongation	18%
Reduction in area	30%
Brinell hardness (estimated)	600

Since the cost of the uranium added 35¢ to each pound of such steel there appeared to be little hope of large tonnage production in 1919, and that was my last experience with ferro-uranium in structural steel.

In the highly competitive field of toolsteels, however, uranium got quite a play for a few more years. It always suffered from the inherent desire to pick up oxygen, so its recovery in the steelmaking process was erratic and a hasty addition at the last minute would usually segregate badly in the ingot. The situation may be described by quoting from Gillett and Mack's book "Molybdenum, Cerium and Related Alloy Steels". Writing in 1925 they said:

"Great claims have been made for its use in high speed toolsteel and some such steel is regularly made with it, but the evidence is far from conclusive that it is of any benefit." This probably was written after reviewing some unsatisfactory tests made by firms which did not get interested in the then-new alloy during the period immediately after World War I.

The present status may be appraised from the fact that Palmer and Luerssen do not mention uranium in the 1948 edition of "Tool Steel Simplified" and Gill and his associates in the exhaustive book "Tool Steels" confine their remarks to a few lines:

"Uranium has been added to high speed steel since it falls in the same family of the periodic chart as do tungsten and molybdenum. However, no conclusive evidence that any benefits were realized can be presented."

The shortage of tungsten did not persist long after the end of the World War. Ferro-uranium therefore became less interesting as a substitute, and I believe went off the American market in 1925 or thereabouts. Furthermore, the raw material, uranium oxide, was no longer available. Prior to that time, Standard Chemical Co. was producing radium from pitchblende and getting uranium oxide as a by-product, but discoveries of rich radium ore in the Belgian Congo were made about that time, and Standard Chemical Co. became merely the importer of radium refined abroad.

Factors in the Selection of Corrosion Resistant Materials

*By F. L. WHITNEY, JR.**

Ease of fabrication (especially field welding without damage), corrosion rate and cost are most important items, but operating factors – such as temperature, concentration, purity and velocity of corrosive fluid, erosion by sludge, concentration cells under adhering solids – are of equal influence on the over-all economics. (R general; SGA-g)

THREE MAJOR FACTORS should be considered in the selection of a material for corrosive service. They are the material, the environment and the economics.

The problem of selection of materials sometimes seems paradoxical. Too often we are so impressed with the importance of one factor that it overshadows other important factors in metal selection. For example, if material is selected for its corrosion resistance and it is later discovered that it cannot be welded in the field, a serious maintenance and production problem is encountered. Again, in certain steel autoclaves, a serious defect was encountered because selection of the steel was made on the basis of corrosion resistance without considering susceptibility to early fatigue failure by temper embrittlement.

Economy is another important factor to consider. To use an absurd illustration, tantalum is not a suitable material for use in the construction framework of a hydrochloric acid plant, since its first cost overshadows its anticorrosive value and near-zero maintenance. Protected steel, on the other hand, is reasonably insensitive to corrosion in this application, is very easy to maintain, and much more economical.

The Material

One of the first considerations in the selection of the metal or alloy is the forms in which it is available. No matter what its other characteristics are, if it is not available in standard shapes and sizes its usefulness as a material of construction is limited. A second consideration is ease of fabrication by standard methods. These methods would include forging, machining, forming, drawing, spinning, welding and riveting. It is also desirable that the condition of the material fabricated by standard methods

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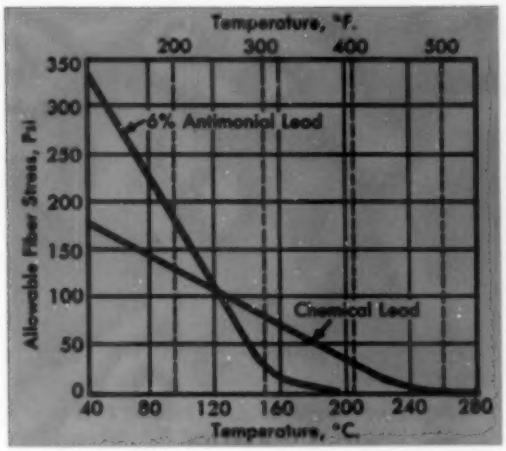


Fig. 1 – Maximum Allowable Fiber Stress in Lead at Various Temperatures. (Courtesy Lead Industries Assoc.)

Fig. 2 – Stress-Corrosion Cracking in Bubble Cap Stamped From Type 304 Stainless Steel (18-8 Cr-Ni, 0.08% max. C)

be as corrosion resisting as the metal in its original form.

The ability to fabricate equipment – particularly large and complicated pieces – by field erection is significant from the standpoint of capital investment and maintenance cost. Tantalum, a highly corrosion resistant material, can be fabricated only under carefully controlled conditions in the shop. Maintenance repairs on this material by welding cannot be carried out in the field; such equipment must be returned to the fabricator for reworking. This means that to maintain production continuity, duplicate or spare pieces of equipment are required which doubles the capital investment. At this moment titanium occupies a similar position. Field tests show that titanium is more corrosion resistant than the stainless steels in many environments but because titanium is difficult to fabricate in the field, the continued use of stainless may be justified in many of these applications.

Another major consideration has to do with the physical and mechanical properties of the metal or alloy. Many materials may possess excellent corrosion resistant characteristics but should not be used if they lack the necessary tensile strength, toughness, and ductility required. The steel autoclaves mentioned earlier are one instance. Another case in point might be the use of lead as a lining for sulphuric acid tanks. Lead has excellent corrosion resistance to sulphuric acid (up to 80% concentration) but at elevated temperatures its use is impractical because of the sharp drop in structural strength. Figure 1 indicates the low allowable stress at various temperatures.

Not only is it important to know that the metal or alloy can be worked by various standard methods to produce desirable shapes, it is imperative to know the effect of stresses (cold or hot work), welding, heat treatment and compo-

Fig. 3 – "Weld Decay" Lines Alongside Joint in Type 316 Stainless Steel (18-12-2.5 Cr-Ni-Mo, 0.08% max. C)

sition on corrosion resistance in specific environments. Using the austenitic stainless steels as an illustration of some of these effects, the following examples are presented:

Stresses – In general, the austenitic stainless steels are susceptible to rapid failure by cracking in alkaline environments when the stress levels approach the yield strength.

Another effect of stresses is shown in Fig. 2. Here a bubble cap formed by a die stamping operation failed very rapidly in an organic chloride environment – a rather dramatic illustration of stress-corrosion cracking.

Welding and Heat Treatment – The sensitivity of austenitic stainless steels to carbide precipitation as a result of welding or heating in the critical zone of 900 to 1400° F. is well known. In spite of this these steels continue to be used in many unsuitable applications which eventually result in premature failures. Figure 3 shows a piece cut from a Type 316 stainless steel exchanger exposed to an organic acid. Type 316 stainless is a very suitable material of construction for this environment, but it must be in its maximum corrosion resisting state, that is, quench annealed. Methods of circumventing the carbide precipitation problem by alloying or lowering the carbon content to between 0.020 and 0.030% have been developed. This usually permits fabrication both in the shop and in the field without subsequent heat treatment.

The cleanliness of equipment to be heat treated is important to prevent contamination or undue structural changes. The importance of this point is illustrated in Fig. 4, in which very damaging oxidation of Type 316 stainless steel was experienced. In this instance residual sand from the blasting operation produced low volatile oxides during the heat treatment which attacked the stainless steel.

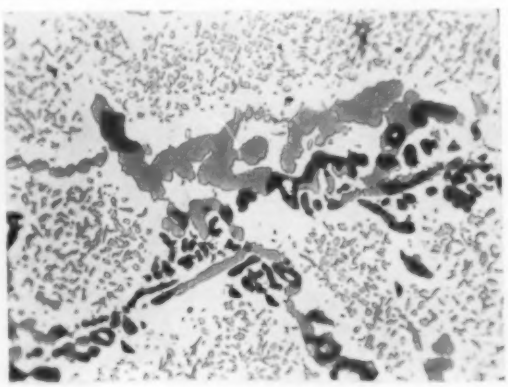
Composition Control – It is often important to establish specifications for material of proper corrosion resistance. For example, the A.I.S.I. specification on Type 316 stainless steel indicates a composition range of from 16 to 18% chromium. Yet in certain phosphoric acid environments if the chromium content is around 16%, the corrosion rate is three to five times greater than that if it were maintained at 17.5 or 18%. Any price-premium incurred – certainly not more than 15% – for so specifying is adequately justified in this instance.

Fabrication Techniques – Another factor in the selection of corrosion resistant materials involves the effect of cold work, lubrication, cleaning and heat treatment in the manufacture of corrosion resistant products, especially of tubular forms. For example, incorrect preparation of a chromium-nickel-molybdenum-tungsten alloy sheet, used in the manufacture of a tubular product, caused the material to fail in service. Our observations indicated that cold working the strip produced a grain boundary condition which promoted intergranular attack in the particular environment. A carburized condition caused by the failure to remove all of the organic lubricant from the tube prior to annealing at elevated temperature aided the intergranular attack.

Fig. 4 – Pitting of Dished Head of Type 316 Stainless Steel, Caused by Adherence of Sand Particles after Blasting.

Castings of the same type of alloy, improperly heat treated and not within specified carbon limits, performed very poorly in service and failed very rapidly due to the presence of massive carbides which promoted interdendritic attack (Fig. 5).

Fig. 5 – Massive Carbides of More Than One Composition in Stainless Steel Casting of Cr-Ni-Mo-W Alloy. 750 ×



Environmental Factors

Temperature plays an important part. In general, the higher the temperature the more rapid the corrosion. A typical effect of temperature is shown in Fig. 6 portraying the performance of lead in a solution of sulphuric acid and salt.

The effect of high temperature and a reducing atmosphere containing carbonaceous compounds on Type 309 stainless steel is shown in Fig. 7. The cracks in the heavily carburized stainless steel are due either to vibration or to raising and lowering the temperature while on stream or while shutting down and starting up.

A similar effect will occur when Type 309 stainless steel is exposed to elevated temperatures which cause the carbon already in solution in the alloy to precipitate. A sigma phase is also

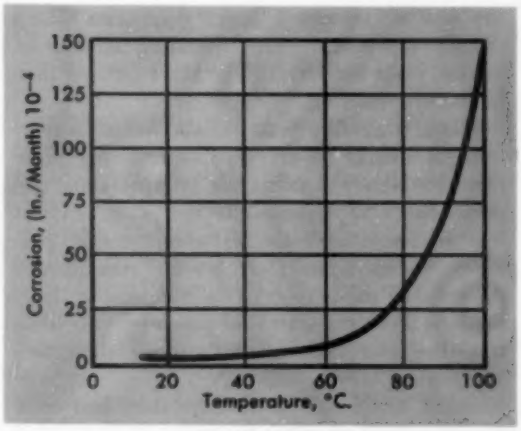


Fig. 6 – Effect of Temperature on the Corrosion Rate of Lead in Acid-Salt Solution – 33.3% H_2SO_4 and 6.7% NaCl. (Courtesy Lead Industries Assoc.)

formed which reduces the room-temperature ductility and makes the material susceptible to fracture.

Velocity – Considerable attention should be given to the effect of velocity of the corroding fluid, because, in general, increases in its velocity increase the corrosion rate. Corrosion increases at a steady rate up to a certain velocity, above which the corrosion rate may accelerate extremely rapidly. An example of this effect is shown in Fig. 8 of lead in sulphuric acid. Velocity affects admiralty metal in the same way. This copper-zinc alloy is useful in sea water up to velocities of approximately 5 ft. per sec. Above this rate the corrosion begins to accelerate. Cupronickel alloys containing approximately

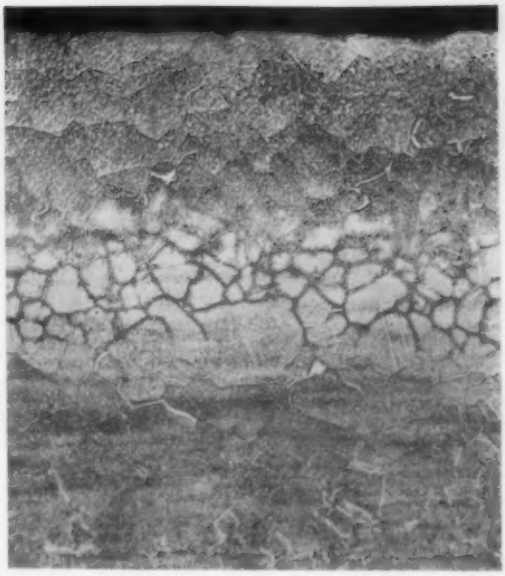
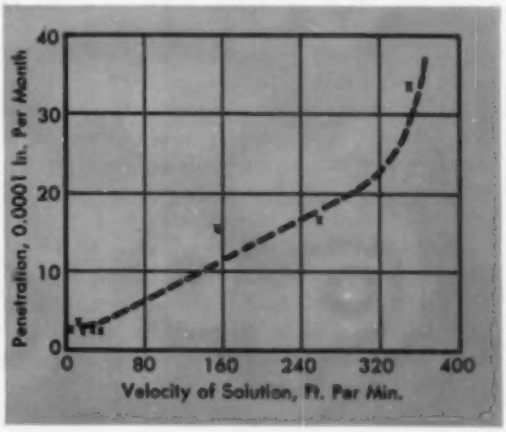


Fig. 7 – Cross Section of Type 309 Tube Badly Carburized (and Cracked) by Hot Carbonaceous Gases. 100 ×. Type 309 is 25-12 Cr-Ni, 0.20% max. C

90% Cu, 10% Ni and 0.75% Fe have better resistance to velocity and pollution in sea water; under some conditions they have resistance in the neighborhood of 20 ft. per sec. Monel is also useful in this and other environments and in general can be exposed to velocities of about 15 ft. per sec. in such waters.

As an illustration of the costliness of overlooking this factor in laboratory tests, consider

Fig. 8 – Effect of Velocity of Corrodent on Penetration Into Lead at 25° C. (77° F.). Solution was 20% H_2SO_4. (Courtesy Lead Industries Assoc.)



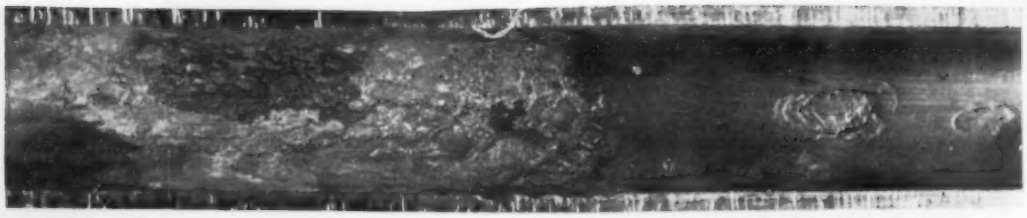


Fig. 9 – Concentration Cell Corrosion in a Cupronickel Tube; 1½ Times Natural Size

a Hastelloy C pump in hydrochloric acid contaminated with hydrofluoric acid. Laboratory tests were conducted in agitated solutions containing these materials and Hastelloy C was found to be most suitable. Accordingly pumps were installed which failed promptly – in a matter of two to three weeks! The calculated apparent velocity was in the neighborhood of 40 ft. per sec., and this particular velocity destroyed the protective film by which Hastelloy C derives its corrosion resistance.

Low velocities are sometimes just as important as high velocities. For example, where admiralty metal has been observed to fail at the water side at normal operating velocities of 5 to 8 ft. per sec., replacements were made with cupronickel. Another unit, a heat exchanger, failed in six months, whereas admiralty lasted for a year or 18 months. It was revealed that the old and small units had operated at high velocities. The engineers undertook to overcome this difficulty by oversizing the new cupronickel unit. As a result, the flow through the unit was less than 1 ft. per sec. Unfortunately, this permitted the solids in the sea water to deposit on the tube walls and cause concentration cell corrosion. Figure 9 shows the corrosion on the interior surface of the damaged cupronickel tube.

Erosion-Corrosion – Although the subject of erosion-corrosion might be considered under velocity, there is perhaps a slight difference in that we are now concerned with liquids carrying solid particles. A solid or slurry will often remove the material's protective film which normally forms in the environment. A condition where this apparently was overlooked is shown in Fig. 10 which reveals erosion-corrosion in a spray nozzle containing finely divided particles of carbon and dust.

Stress-Corrosion Cracking – Not only do induced stresses within the metal during fabrication present a problem but also stresses induced by operation. Thus, thermal or mechanical shock or stress becomes an additional factor in the selection of the material. This is illustrated by the failure of Type 316 stainless steel coils alternately heated with steam and cooled with cold water. Corrosion of an intergranular nature from the steam side started the reaction and the thermal shock or stress completed it.

Corrosion Testing – If the engineer has no pertinent past experience, the corrosion test is an effective tool to assist in the selection of materials of construction. This is true only when the test is conducted under conditions which exactly reproduce plant operating conditions. Hence, plant tests tend to be more reliable than laboratory tests.

When laboratory tests are conducted, serious thought should be given to reproducing those factors which will affect the interpretation and performance of materials *in the plant*, such as the mass-volume ratio, erosion-corrosion, viscosity, velocity, purity of chemical constituents, presence of solids or crystals, temperature (particularly heat transfer) and pressure. To illustrate the importance of this consideration, two experiences are quoted.

In the first incident, the laboratory had completed a new process development and asked the corrosion specialists to recommend or specify

Fig. 10 – Effect of Erosion-Corrosion Inside a Spray Nozzle Carrying Fine Particles of Carbon and Dust

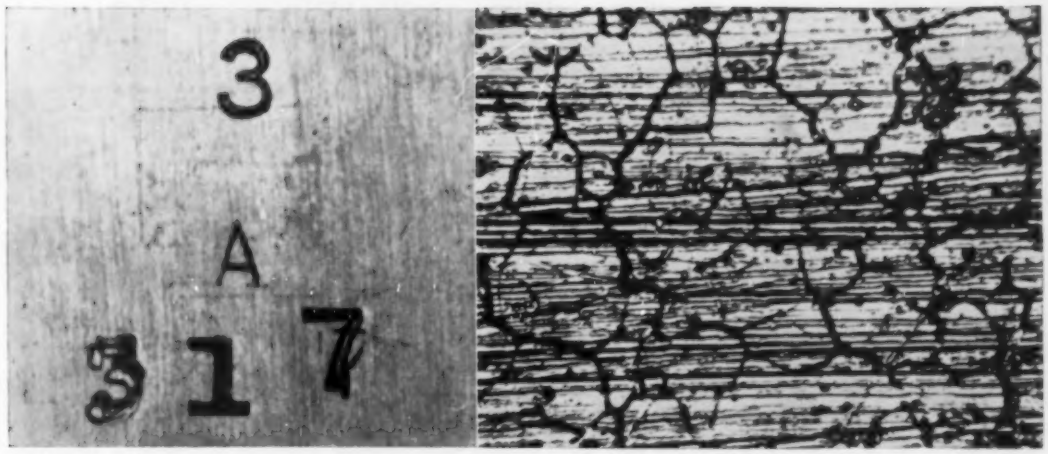


Fig. 11 – At a Magnification of Three Diameters a Sample of Type 317 Stainless Appeared Unharmed by Boiling HNO_3, but When Enlarged 150 Diameters There Is Plenty of Evidence of Intergranular Attack Plus corrosion of the "Ditch Type"

materials of construction. Analysis of the process revealed only one factor about which there was some doubt, and it involved an acidulation at an elevated temperature while adjusting the pH of the solution. Following this step the agitated mass was to be cooled for crystallization. Management wanted a quick answer to the problem. No time was allowed for sufficient investigation of the corrosion problem. However, it was agreed by those concerned that the most corrosive condition should probably be experienced at the elevated temperature. Tests were made under these conditions, and indicated that Type 304 stainless steel should be suitable. A clad vessel was consequently installed which failed by pitting attack in about a year's time. A much more thorough investigation, after the fact, showed that the pitting was the result of concentration cell corrosion fostered by the adherence of the crystals to the surface of the vessel during the crystallization step in the process. This was about a $10,000 error in judgment!

The second incident involved a process change which resulted in the premature failure of equipment. Since it was considered at that time inadvisable and impractical to use plant equipment for experimentation, laboratory tests were resorted to in an attempt to reconcile the old and the new processes and to explain the accelerated corrosion which was observed. Every effort was made to set up the testing apparatus to duplicate actual operating condi-

Fig. 12 – A Surface Which Merely Appears Stained Somewhat Irregularly Is Really, When Magnified 150 Times, Badly Pitted

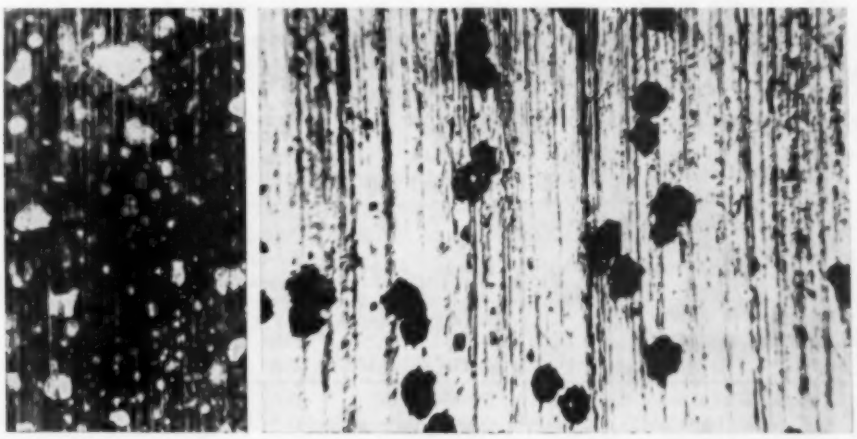


Table I—Corrosion Rates for Reaction Vessel

Material	Mils Per Yr.	Mils Per Charge	Remarks
Everdur	31	0.026	Uniform corrosion
Type 304	3	—	Pitted; unusable
Monel	25	0.021	Uniform corrosion
Steel	112	0.094	Uniform corrosion

Table II—Life Expectancy Based on Forecasted Production

Material	Thickness	Useful Life
Everdur	¼ in.	4 yr.*
Monel	¼	4.2
Steel	¼	4.4

*Checks actual plant performance.

tions and yet the results were highly contradictory. In the first place, the laboratory results showed that the old process was more corrosive than it actually was, and second, laboratory tests indicated that the new process was less corrosive than the old process. Based on plant experience, it was evident that laboratory tests were not going to give the answer.

So in spite of the urgency of the production problem, the plant equipment was shut down and set up to run corrosion tests on both the new and old process. These tests checked actual plant experience and revealed that the accelerated attack was caused by erosion brought about by a change in the mass-volume relationship at one point in the new process.

When short-time tests are conducted in the laboratory or field, observation of the specimens by the unaided eye may be inadequate. It is suggested that all samples be examined under the microscope to determine the type of attack. As an illustration, Fig. 11 shows a sample of Type 317 stainless steel exposed to boiling nitric acid. To the unaided eye, based on corrosion data measured in terms of weight loss, the sample appears to be relatively unattacked. However, examination under the microscope at 150 diameters reveals that attack is intergranular in nature and is of a ditch type suggesting that failure will occur in the not too distant future and that the material is of questionable use. In a similar category Fig. 12 shows an exposed sample which, except for stains, appears to be unattacked. However, at 150 magnifications a vicious form of pinhole pitting is observed, which would result in early failure of this material in this environment, although the weight loss was negligible.

Economy

To illustrate the influencing effect of corrosion rates on economy, take the following example from experience: A reaction vessel fabricated of Everdur 1010 has a service life of four years. This was not particularly satisfactory and plant corrosion tests were conducted to find a better material of construction. Materials tested were Everdur for control, Type 304 stainless steel, Monel and carbon steel.

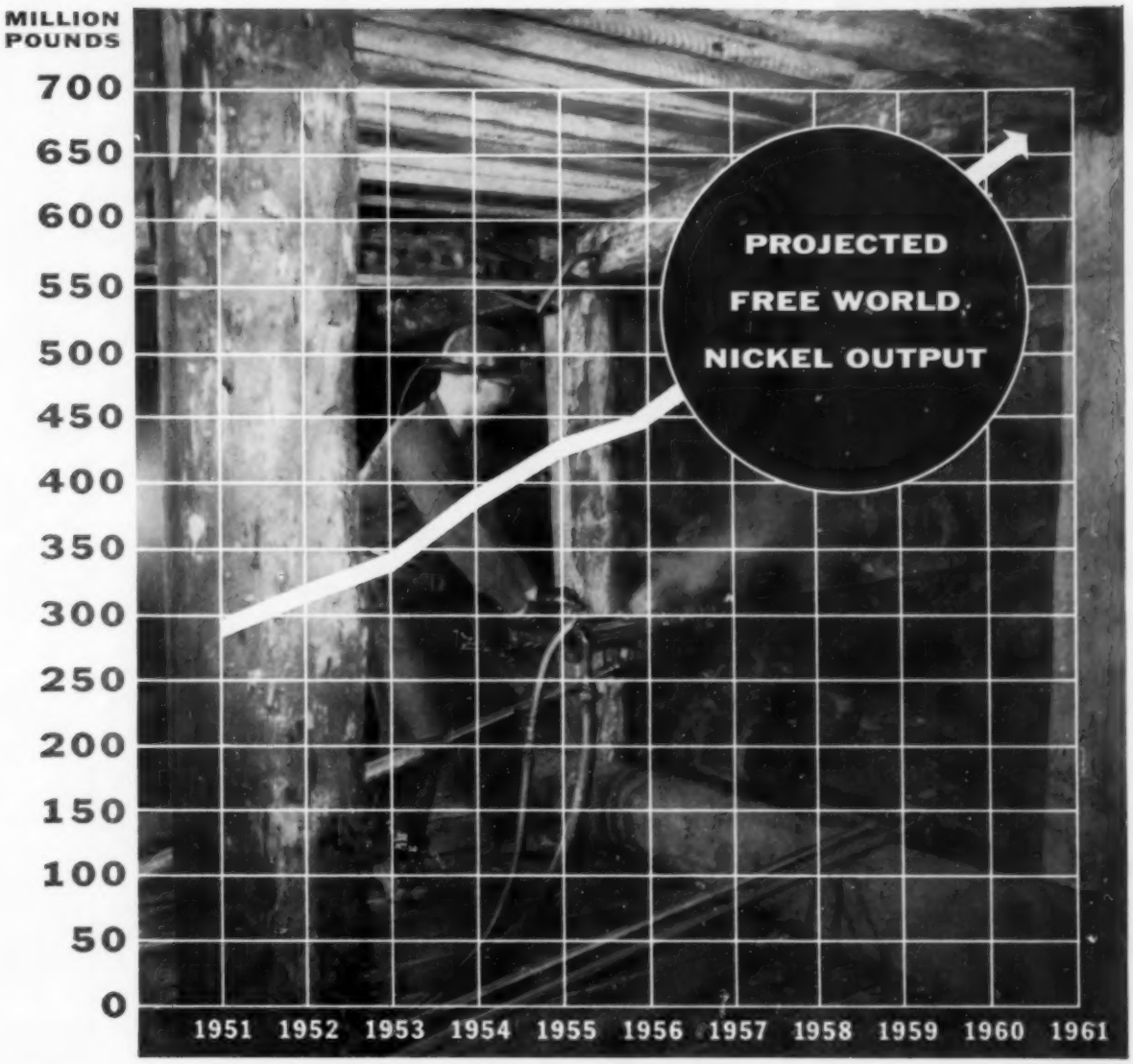
The corrosion test indicated that Type 304, while it had a very low corrosion rate, sustained pitting attack which cannot be correlated with service life. The other three materials, Everdur, Monel and steel, all sustained uniform corrosion, the only type of corrosion which can be evaluated safely from an engineering standpoint. Based upon the corrosion rates shown in Tables I and II, Everdur, Monel and steel each have a service life of approximately four years if the reactor shell is made of appropriately thick plate. The estimated cost and saving are shown in Table III, which indicates that although steel has the highest corrosion rate, it will result in the greatest savings if additional thickness is employed.

Table III—Estimated Cost and Savings

Material	Life Expectancy		Cost			
	Charges	Years	Installed	Annual	Annual Savings	Return*
Everdur	4800	4	$ 9,850	$2,460	—	—
Monel	5000	4.2	10,800	2,570	$110 (loss)	None
Steel	5300	4.4	5,200	1,180	1280	Note *(a)*

*Based on additional investment on Everdur.

(a) Two savings: $4650 reduction in capital investment plus $1280 annually.



Another 50% advance in nickel industry's production capacity

Paced by Inco-Canada's new developments in Manitoba, producers put 1961 Free World nickel output at 650-675 million pounds a year—up 130% over 1951

In 1951, the nickel industry of the *Free World* produced about 290 million pounds of nickel.

Last year, the over-all output of the industry set a new record high of 450 million pounds.

This was an expansion of more than 50% in five years: a substantial production boost that indeed benefited industry, but only after vital defense and government stockpile needs were given preference.

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Right now Inco-Canada, with years of exploration behind the project, is pushing construction at its new Manitoba mines: developing in the far North a new, big-tonnage nickel-producing area.

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In 1961, this should lift Inco-Canada's nickel output to 385 million pounds a year. A hundred million more than in 1956!

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With 1961 capacity anticipated at more than twice what it was in 1951—and with continuing exploration—nickel users are assured of more nickel in their future.

The International Nickel Company, Inc., New York 5, N.Y.

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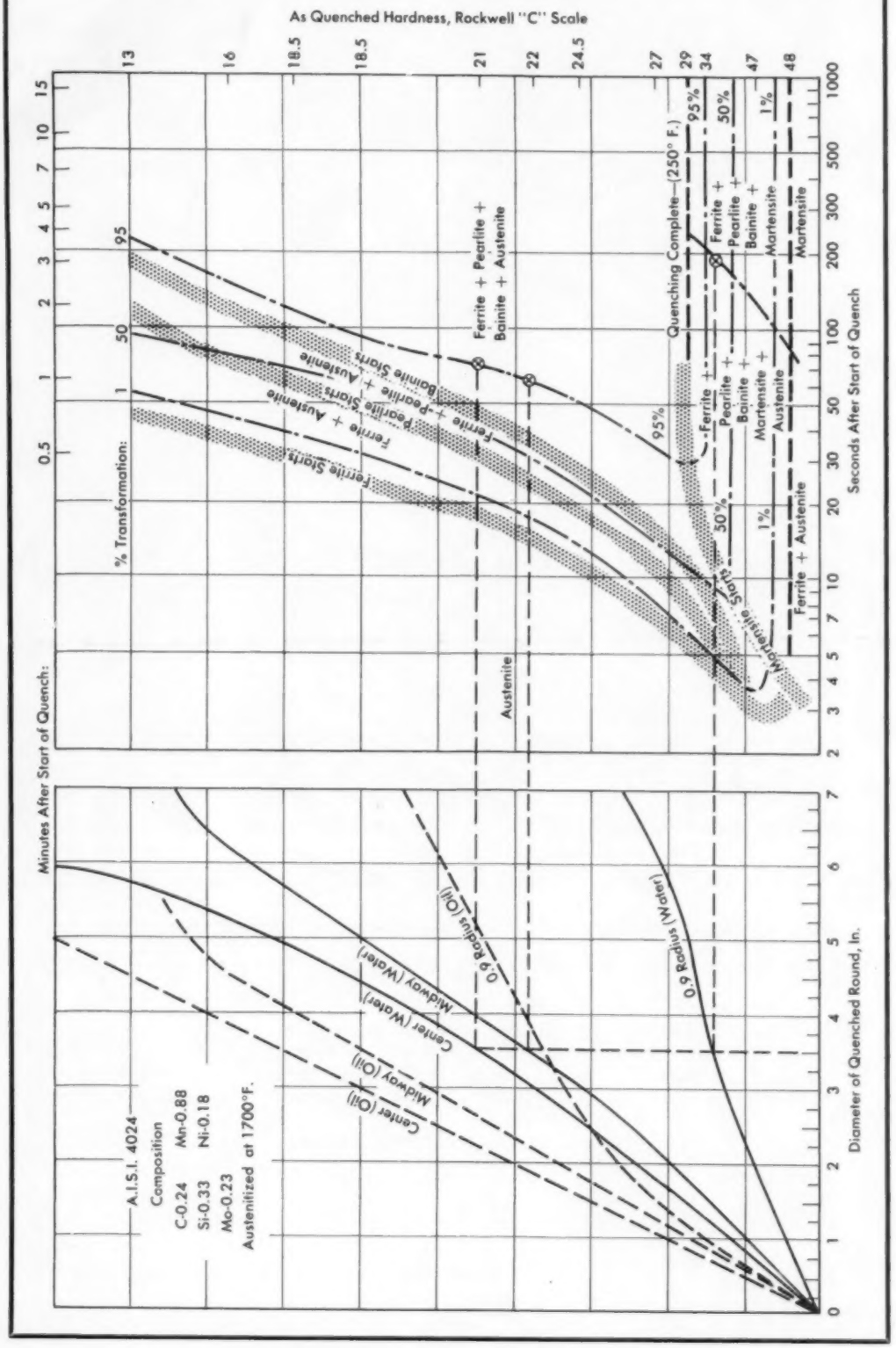
Heat Treatment Diagram for A.I.S.I. 4024

By D. J. Blickwede and R. C. Hess
Bethlehem Steel Co.

See Explanatory Note on p. 114



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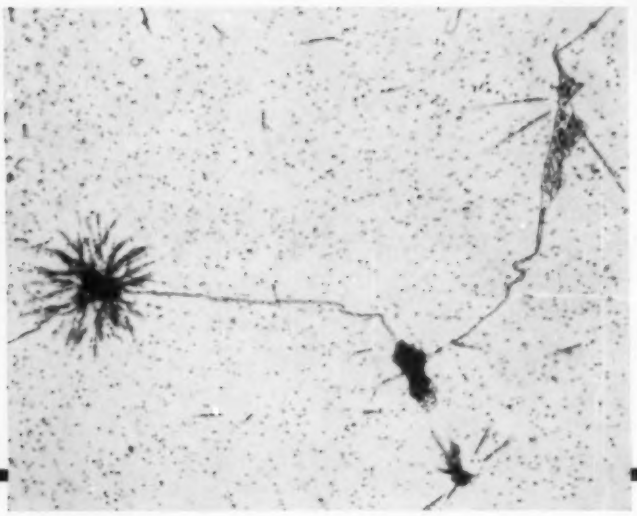
—Blue Ribbon Award Winners, 1955, A. S. M. Metallographic Exhibit



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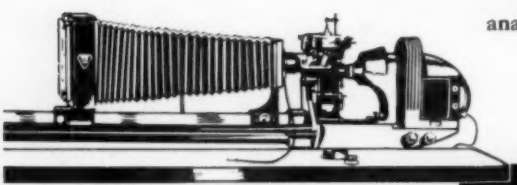

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Over-All Statement of the Problem

*By the Panel Chairman – ALFRED H. PETERSEN**

THE PURPOSE of this panel is to consider aircraft materials for thermal flight up to 1200° F. This is a rather arbitrary limitation, but in the brief time allotted to us, it does not seem feasible to attempt to explore every flight regime and all the alloys which might be used throughout.

For the immediate future, we may consider that this 1200° F. will be primarily concerned with the limitations of manned vehicles and – depending on whose chart you looked at last – will bring us out beyond Mach 5 or possibly Mach 6 in aerodynamic flight corridors up around 100,000 ft. in altitude. Again, depending on whom you last talked to, we can be discussing sonic, supersonic or hypersonic speeds – or "thermanic", "super-thermanic" or "hyper-thermanic" regimes.

In the short time allotted to us, each contributor will be brief, but we hope to establish the real requirements, a few important characteristics for materials and their limitations. If we can do this it will help both the designer of aircraft and the producer of his materials to order their thinking and thus narrow the wide scatter in viewpoints and attitudes we apparently have today. For time limitations we cannot discuss the practicability of refrigeration. It must be borne in mind that its use will impose weight penalties. Nor will we talk of transpiration, emissivity, sublimation or radiation.

I would like to think that we are going to talk today about material and design requirements which, at given times and temperatures, would be equivalent to our current aluminum alloys in strength, stiffness and fabricability at room temperature.

I have the impression that the knowledge to design a commercially producible airframe to operate at the suggested limit of speed and temperature is somewhat wanting at present. We need a much more intimate knowledge of both current and new materials, in terms of elastic stability, plasticity, ductility, fatigue resistance, crack susceptibility and creep tendencies. Designers have much to learn about diffusibility, convection, conductivity, thermal expansion of structures and thermal gradients through structural joints. When we know these things, we may very well develop structures which will not look much like those we have been accustomed to seeing made of aluminum.

Our first speaker will give the metallurgist's concept of the material which we will require.

Our second speaker will attempt to outline a matter of real concern – the fabrication problems we can see developing when we put into production the materials we have been testing.

The other speakers are going to tell us what

*Group Engineer, Producibility Methods, Lockheed Aircraft Corp., Burbank, Calif. This and the following papers were presented by A.S.M. at the Western Metal Congress on March 27, 1957.

they know of the problem as we have presented it to them and their concept of materials available, at present and in the near future, to meet these requirements.

Actually many heat tolerant materials are being used today in conventional aircraft structures, near engines, afterburners and equipment lines operated and fed by heated engine air and exposed to the temperature of 1200° F. we have set as a limitation. Thus, we must assume that the proper materials are now available, or can be made commercially. Our basic problem arises from the fact that designing the entire structure of current materials, using the usual criteria, will make the structures heavier and more difficult to build, thus imposing weight and cost penalties which are entirely impracticable at peak production rates.

If the next generation of fighters is to be supersonic and capable of operating at high Mach numbers in level flight at all altitudes for periods of more than 10 min., we must pin-point our criteria, modes of construction and material requirements without delay.

The Metallurgical Requirements

*By LEO SCHAPIRO**

You may be expecting to hear me use the words fatigue, impact, grain size, microstructure, and other recognized metallurgical terms. I propose to relegate these to the discussion period, and to only talk about *strength*. Load-carrying capability is what I mean by "strength".

In the words of a recently popular song about love, strength is a Many Splendored Thing. For one component of an air-borne vehicle we mean tension yield strength. For a different component, compressive yield strength governs the choice of the material to be used and its thickness. Still another component is designed by modulus of elasticity, another by bending modulus of rigidity, another by shear strength, and — when temperature has to be likewise sustained — we must deal with even different strength parameters.

Strength is such a many splendored thing I do not have the time to discuss all the parameters. But I do want to lay the ground work for this afternoon's discussions by stipulating one strength parameter that a material should possess so that an air-borne vehicle may be constructed of this material and be capable of sustaining a temperature of 1200° F. on its aerodynamic surfaces. This parameter is *yield strength*.

My diagram is a pictorial history of man's progress in increasing his speed of travel through the air. The sharply ascending line plots the speed versus the year in which the speed was first attained by military airplanes commonly designated as fighters. There are no points on this plot but the original from which it was copied has all the points designated by the airplanes' names. This plot is not a faired line drawn through scattered points; the actual points are closer to and on the drawn line than any self-respecting set of test data would have a right to be. Leaving off the points avoids classification problems. The many airplanes represented by this plot differed from each other in the engines that powered them and in their appearance. But they had one thing nearly in common. Their 1 G stress level didn't differ too much from the value of 70,000 "Index".

I should like to explain my use of the word "index" and you will recognize it as nothing new. By index I mean strength in lb. per sq.in. divided by density in lb. per cu.in. If you play with these units mathematically your pencil cancels out words and you have one inch left. It would sound strange to express a strength parameter in units of inch, so "index" will serve temporarily.

If we examine the 70,000 index value in terms of the density of aluminum of which these airplanes were constructed, we convert this value to a 1 G stress of 7000 psi. for an aluminum airplane. Now the prestidigitator waves his magic wand and you must watch him closely. If an air-borne vehicle is traveling fast enough to receive a surface temperature of 1200° F. from

*Chief Metallurgist, Douglas Aircraft Co., Inc., Santa Monica, Calif.

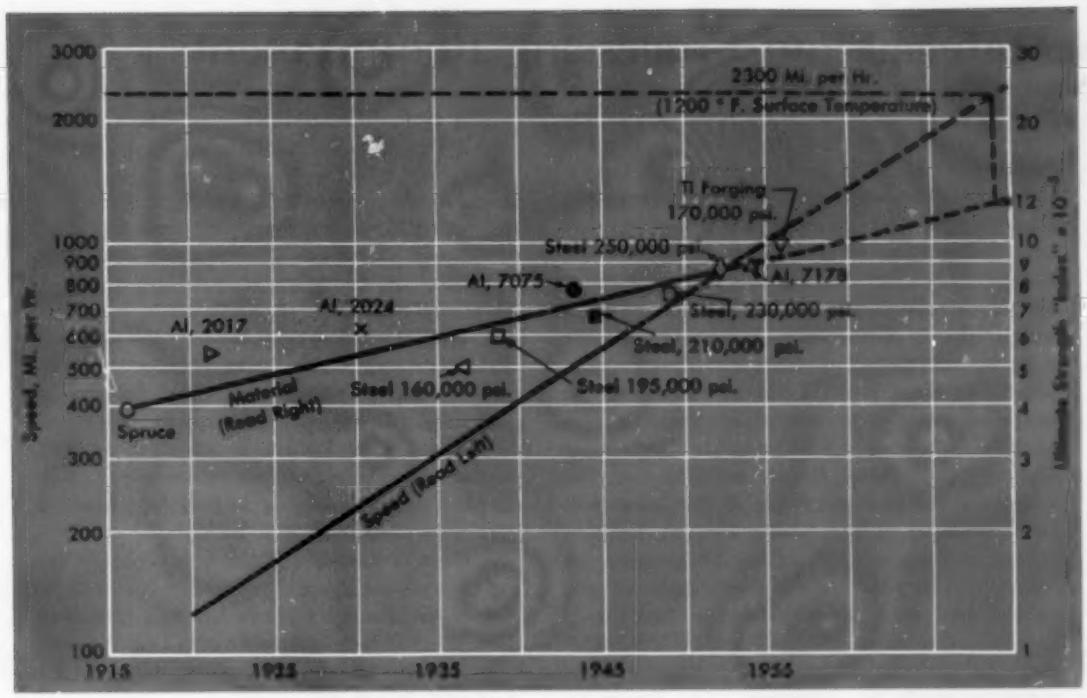

Fig. 1 – Progressive Increase of Speed in Aircraft and of Ultimate Strength Index of Materials of Construction Then Available. Ultimate strength index is defined as ultimate strength in lb. per sq.in. divided by density in lb. per cu.in.

aerodynamic heating, it had better be capable of withstanding a limit load factor of at least 12 G or it will be torn apart when it performs its required maneuvers. This means that the components of this air-borne vehicle (which, by the way, are designed by *yield* strength rather than ultimate strength) should be made of a material whose *yield* strength is about 800,000 index (12 times 70,000 with a little rounding out).

Perhaps the prestidigitator went too rapidly. Let us try it again.

As the history of increasing speed shown in the diagram was being made, the limit load factors increased. Since 1 G stress didn't change much through the years, the materials of construction had to increase in yield strength to sustain the increase in limit load factor. The rather flat line on the diagram is a history of these materials plotted at the year in which each was introduced. (I hope it isn't too much of a complication to plot tensile strength index here instead of yield strength index.) We'll do some sleight-of-hand later and convert these back to a yield strength parameter. Actually, the ordinates at the right are not tensile strengths but rather an index of tensile strength – again, strength divided by density.

This plot names all the materials. It is interesting to compare the strength parameter with the record of speed attained with the aid of constructional materials of increasing strength, and make some predictions by extrapolation.

The lowest speed for which a 1200° F. surface temperature can be calculated is indicated in this chart as 2300 mi. per hr. and the corresponding ultimate strength index is indicated to be 1,200,000. Remembering that this index is for tensile strength and using the well known two-thirds factor for relating yield strength to tensile strength, this extrapolation indicates that the material we desire for 1200° F. operation should have a yield strength of 800,000 index.

So it is a coincidence that my two methods of crystal gazing give me similar answers. I know that many assumptions are inherent in my methods of prediction. I know that if we can increase the power from propulsion units at a faster rate than we have been able to in the past, designers will be able to utilize materials of lower yield strength index than I have indicated. But I have erected a flagpole about which the May Dance can swing.

Material and Processing Requirements

*By F. R. KOSTOCH**

In the constant search for high strength, other significant requirements have often been overshadowed or even ignored. The first (and always first) criterion for airframe design is *weight*. Consequently the well-known strength-weight ratio is emphasized. But, there are other ways to save weight which are less well recognized. In sheet product (the one most used in airframes and the product which I will discuss) available sizes and tolerances are significant factors. In general it can be said that the larger the size of sheet available, the lower will be the weight of the fabricated part, because splices are not needed. Closer tolerances for thickness can also reduce the weight of the part – and here I pause to mention that this is especially important when we start building with steel, for every cubic inch of it weighs three times as much as aluminum. The American Aircraft Industries Assoc. has developed a chart showing sizes versus gages for steel. These requirements, coupled with much closer dimensional tolerances, are known to be difficult. Nonetheless this is what will be needed if steel products can become competitive with the lighter metals in aircraft design.

After weight, the next most important criteria are availability and fabricability. By availability is meant that products can be bought in normal fashion, in production quantities of uniform and usable material, and not a conglomerate of odd pieces to be sorted and stacked for specific uses.

Fabricability is always a problem because the desirable strength characteristics are usually diametrically opposed to those which make for easy fabrication. However, all the strength in the world is no good if you can't make parts. Fabricability includes a number of items which will be enumerated and briefly described. No priority is implied by the order of numbering.

1. *Reproducibility* – As sheet alloys become more and more difficult to form, it is obvious that uniform response from lot to lot is essential.

2. *Forming* – Bending, stretching and drawing are the three major forming methods. Each requires a different characteristic or set of characteristics in the metal, but since any given lot of material may be subjected to any or all methods the product must have *all* the necessary characteristics. Once again I make the point that we cannot segregate material for production. Tight-bend radii are essential, hence we must have good local elongation. Stretching, on the other hand, utilizes uniform elongation coupled with a resistance to necking. Drawing requires a combination of both.

3. *Heat Treatment* – While it is probable that the desired mechanical properties can only be had in our strongest alloys by heat treatment, thought must be given to its effect on the parts being manufactured. Severe quenches will twist sheet metal parts into what men in the shop call pretzels, and these have poor aerodynamic and structural properties, even if they can be assembled to supposedly matching parts. At present the precipitation hardening alloys have what seem to be the best heat treating characteristics. If the producers can supply a flat sheet of close tolerance in a condition of good formability and which can subsequently be hardened to a high strength at a relatively low temperature, the airframe manufacturer will have a good material.

4. *Scale* – The nature of scale produced by heat treating is also of interest. If a scale will be formed, we very much want one that can be removed without using a chipping hammer.

5. *Welding* is one of the first methods of joining that comes to mind in steel construction. The ability to make light-weight joints and splices (if the weldment be heat treated to a high percentage of the basis metal strength) is a juicy plum for the designer. Likewise in complex assemblies it is highly desirable to be able to weld after heat treatment, even if some strength is lost.

6. *Brazing* – There is much talk and a correspondingly great effort today toward fabrication by sandwich construction. Brazing of corrugated core to face plates is one of the most common. To achieve bonds which have adequate load-carrying capacity at the temperatures we are discussing (1200° F.), brazing alloys with high

*Section Head, Material and Process, North American Aviation, Inc., Los Angeles. Advanced methods of forming and of machining were discussed at considerable length in two other sessions at the Western Metal Congress. It is planned to publish the papers in a future issue.

melting points are used. Furthermore, the brazing cycle and the heat treating cycle must be compatible. It would be highly desirable if they could be done simultaneously, but at least the alloy must not be changed into a non-responsive condition by the brazing cycle.

Corrosion resistance is one more requirement of a suitable alloy. Our customers have always felt that *any*, and I emphasize any, rust is undesirable; some even insist it is dangerous. If, therefore, alloys which have all the other desirable characteristics are not corrosion resistant we have two courses open to us: We can educate all the customers' personnel to recognize where rust is critical and where it is not; on the other hand, we can provide a protective finish. The first approach may be impossible in the normal life span; the second poses a very serious problem with regard to weight. For example, consider sandwich construction. Here we use very thin material (0.0002 to 0.0010 in.). If we must apply several thousandths of plating or paint we rapidly lose the advantage of light weight in high-strength steel construction.

Each of these requirements which I have outlined is an important criterion in the final selection of the material which will be used on an airframe. It, therefore, behooves the suppliers to examine them carefully very early in the development of high-strength materials.

Titanium Alloys

*By ROBERT I. JAFFEE**

It is a pleasure to lead the presentation of metals for fast aircraft because jet aircraft of the Mach 1 to 1.5 class has been the mainstay of the titanium industry. Six major products have been used to date.

Unalloyed titanium sheet has been mainly specified as 70,000 psi. minimum yield. It has been used at relatively low temperatures for moderately stressed structural parts or for non-structural applications, generally with spot welded or fusion arc welded joints.

Ti-8Mn sheet (an alpha-beta alloy containing only a beta stabilizer) has been designed for 110,000 psi. minimum yield strength, and used in structural applications up to about 600° F., generally riveted with Monel rivets.

Forgings of the Ti-6Al-4V and Ti-4Al-4Mn alloys – alpha-beta alloys containing both alpha stabilizer (Al) and beta stabilizer (Mn or V) – have had 120,000-psi. minimum yield strength, and were made into wheels, rings and blades of jet engine compressors working up to 800° F.

The Ti-2Cr-2Mo-2Fe alloy (an alpha-beta alloy with stabilized beta and a eutectoid former, Cr) has 110,000 psi. minimum yield strength, and has been used chiefly in forgings for jet engine compressor wheels, and to a more limited extent as a sheet alloy; in the latter, it is considered equivalent to Ti-8Mn sheet.

The all-alpha Ti-5Al-2.5Sn, with 110,000 psi. minimum yield strength, has been used up to 800° F., generally in welded sheet applications.

Apparent Possibilities – So much for the present. What are the apparent possibilities for the topic of this conference – really high-temperature service? While it is difficult to canvass this situation in brief compass an effort has been made in the graph on p. 102, Fig. 2, giving short-time tensile strength of three families of materials at elevated temperatures.

The band at top, in black, represents alpha-beta alloys containing both alpha stabilizers (aluminum) and beta stabilizers (manganese, molybdenum or vanadium). Strength versus temperature curves for Ti-4Al-4Mn and Ti-6Al-4V are quite similar and are located near the bottom of the band. (As will be pointed out, the Ti-6Al-4V alloy in sheet form can be heat treated to the higher strengths shown in the isolated line at the top of the chart.) Molybdenum is a somewhat better addition than vanadium for retention of strength at elevated temperature. The Ti-6Al-4Mo alloy occupies positions at the top of the band up to 700° F. As the aluminum content of an alpha-beta alloy increases, strength is maintained to somewhat

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higher temperatures, and the Ti-7Al-3Mo alloy is the strongest of this group from 800 to 1200° F. Mr. Schapiro's index for Ti-7Al-3Mo is about as follows, figuring high-temperature yield stress at 80% of the corresponding ultimate strengths shown in Fig. 2:

Temperature	Strength Index	Yield Index
800° F.	800,000	650,000
1000	660,000	525,000
1200	450,000	350,000

Alpha-beta alloys containing aluminum and eutectoid-forming elements, notably chromium, occupy a narrow band at about the center of the black band in Fig. 2 up to about 800° F., but drop off sharply to the low side at higher temperatures. These alloys are represented by the following which have been extensively studied:

Ti-2Cr-2Mo-2Fe
Ti-5Al-1.3Cr-1.3Mo-1.3Fe
Ti-5Al-2.75Cr-1.25Fe
Ti-3Al-5Cr

They have excellent strength-temperature relationships and are highly heat treatable, but may be susceptible to eutectoid decomposition and instability at temperatures above 800° F.

The strengths at elevated temperature of various all-alpha alloys fall within the broad band in white in Fig. 2, just below the stabilized alpha-beta alloys. The compositions with high alloy content are located at the top of the band. Ti-13Sn-2.75Al is highest to about 800° F.; Ti-8Al-2Cb-1Ta then takes over as strongest of the all-alpha varieties at 1000 and 1200° F. A curve for Ti-5Al-2.5Sn represents the bottom border of the white band. The thermal stability of the two stronger alloys above 800° F. has not yet been established, while the lower alloy Ti-5Al-2.5Sn has been shown to be thermally stable up through 1000° F.

The fourth general class of titanium alloys, the alpha-betas containing only beta stabilizers, occupy a position just above the center of the white band to 700° F., and then drop off sharply. Representative of this class is the well-known Ti-8Mn and the Ti-2Cr-2Mo-2Fe alloy. They have quite similar strength-temperature properties, with the Ti-8Mn having a slight edge in strength.

It might also be remarked that titanium has been strengthened about two-fold by alloying, when tested at room temperature, and five-fold when tested at 1000° F.

Creep Strength and Thermal Stability – It is hardly news that tensile strength does not tell the whole story. Creep rate is of prime importance to jet engine parts, for example, and the various types do not show the same strain-rate sensitivity in proportion to their elevated-temperature strength. For example, Fig. 3 compares in white lines the tensile strength with the creep strength of a typical alpha alloy, and in black lines the corresponding data for a stronger alpha-beta alloy. The latter has superior tensile strength up to 1100° F., but its creep strength drops sharply and is less than the creep strength of the alpha alloy above 700° F. These values decrease to unusably low figures for the alpha-beta alloy Ti-6Al-4V above 800° F., and for the alpha alloy Ti-5Al-2.5Sn above 900° F. These are about the limiting temperatures for structural applications of the present commercial titanium alloys.

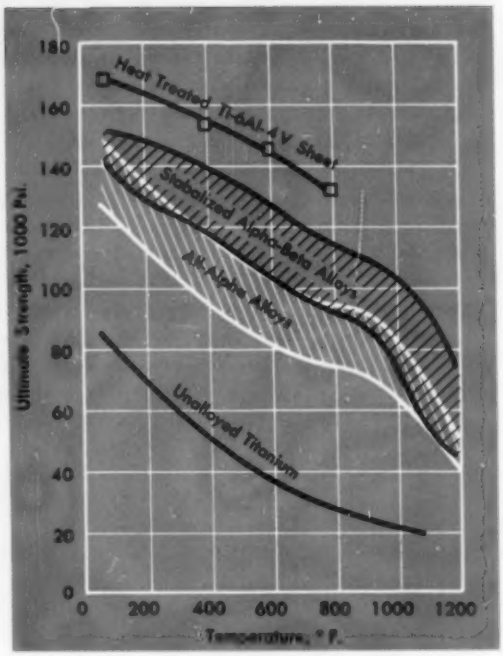


Fig. 2 – Tensile Strength of Various Types of Titanium Alloys When Tested at Elevated Temperatures

The thermal stability of both these types has been of major concern. Indeed, it is apparent that more data of this nature are available on titanium alloys than on any other material intended for use at elevated temperatures – not because they are intrinsically more unstable, but because acceptance tests for titanium alloys are considerably more stringent than for other materials.

It has been found that if the hydrogen content

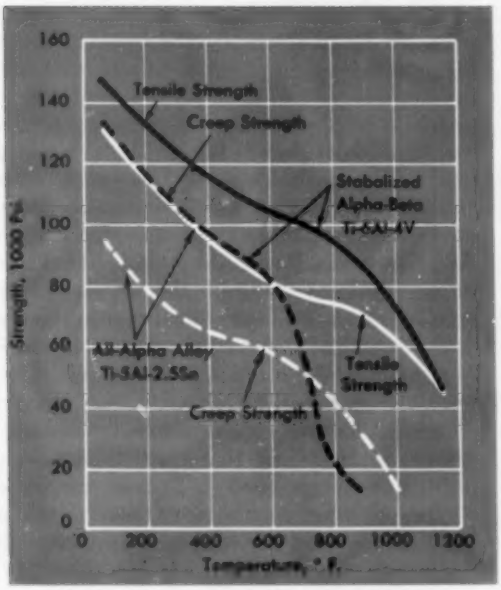


Fig. 3 – Comparison of Tensile and Creep Strength of Two Types of Alloys. Creep strength is defined as the stress to produce 0.5% plastic strain in 1000 hr.

is reduced to below 150 ppm. and stabilizing heat treatments are performed, the thermal stability is quite good for alloys wherein the beta phase is stabilized (by Mo, V and Mn). Properly heated treated, these alloys are thermally stable for any contemplated service life at any usable temperature. Alloys containing much chromium, which is subject to beta eutectoid decomposition, are limited to uses at about 800° F.

Contamination by oxygen, entering the skin at 800° F. and above and diffusing into the underlying metal, will cause a loss in ductility in some alloys, as measured by the reduction of area in a room-temperature tensile test. This is especially true of Ti-2Mo-2Cr-2Fe. In alpha alloys with high alloy content, thermal instability from the development of an ordered structure has been discovered and this may limit the usable alloy content of alpha alloys.

Future Needs

This completes a quick look at a few facets of our present alloys. What are the future needs and what are the prospects that titanium can meet them?

Perhaps the greatest immediate need is for much higher strength (approaching 200,000 psi. when tested at room temperature) for use in aircraft forging and sheet applications at 600 to 800° F. This is a large jump in strength from the alloys currently being used having strengths of 110,000 to 120,000 psi. Any such strength level dictates heat treatment, and this in turn requires alpha-beta or beta alloys.

As shown in the top line in Fig. 2 corresponding to Ti-6Al-4V, this alloy is readily heat treated to strengths of 160,000 to 170,000 psi. The curve shows tests on sheet material after having been heated 1 hr. at 1550° F., quenched, and then aged 24 hr. at 1000° F. The alpha-beta stabilized Ti-4Al-4Mn alloy may also be heat treated up to 170,000 to 180,000 psi., while the range of 180,000 to 200,000 psi. may be attained with alpha-beta alloys containing the eutectoid forming elements iron and chromium, such as Ti-5Al-1.3Fe-1.3Cr-1.3Mo and Ti-5Al-2.75Cr-1.25 Fe. These are used mostly for forging, and, if worked properly in the temperature range of the alpha-beta field, excellent combinations of high strength and good ductility are readily attained.

For heat treated sheets, production problems are much more severe. What is needed is a solution-treated alloy sheet supplied by the mills in the soft, formable, flat condition which may be formed and then aged to final properties by the airframe fabricator. Toward this end, the Department of Defense has instituted the Titanium Sheet Rolling Program to manufacture on a production basis as heat treatable sheet four alloys, Ti-3Al-6Mo, Ti-4.5Al-3Mo-1V, Ti-2.5Al-16V, and Ti-6Al-4V. The minimum tensile properties aimed at are 180,000 psi. ultimate, 160,000 psi. yield, 10% elongation – all at room temperature – and 120,000 psi. minimum yield at 800° F. This target may not be quite reached by the alloys in sheet form, but from present indications, 170,000 psi. minimum ultimate at room temperature with 6% minimum elongation seems to be reasonable and attainable.

High creep strength at higher temperatures is needed for forgings and weldable sheets for a number of applications in advanced aircraft, particularly in jet engine compressors for engines of the Mach 2.5 to 3 planes. For such engines, compressor outlet temperatures of 1200° F. are anticipated. Titanium alloys suitable for this service have not yet been commercialized, although there is, of course, a great deal of development work going on. At the present time, it appears doubtful that a titanium-base alloy suitable for service at 1200° F. can be produced. Present indications are for an alloy for 1000° F. top.

Steels for Aircraft

*By R. B. GUNIA**

There are five basic metallurgical requirements that must be met if this country is to build the world's fastest and best airplanes:

First, and perhaps the most important, is *strength*. A minimum tensile strength of 200,000 psi. or higher willl be necessary to meet design requirements, and the metal must maintain this strength throughout the range of temperature encountered in flight.

Second, the metal must have *corrosion resisting* properties. (Under certain conditions, this requirement may become less significant.)

The third requirement is *producibility* which we will discuss in more detail later.

Fourth is *availability* in large tonnages and from numerous sources.

The final requirement is *fabricability* into finished assemblies, by equipment and skilled workmen in many plants.

We strongly believe that steels best meet these new aircraft requirements.

Types of Steel Available

Suitable types for airframe construction are as follows:

1. The martensitic steels, A.I.S.I. Types 410, 420 and 422 modified.
2. The "forced" or "delayed" transformation steels which develop their strength by refrigeration.
3. The steels age hardenable by transformation.
4. The age hardenable austenitic stainless steels, strengthened by either a carbide or a nitride precipitate.
5. The austenitic stainless steels cold worked to high tensile strengths (Types 301, 201, 202, or U.S.S. "Tenelon").
6. The constructional alloy steels which are heat treatable to high strength levels, such as S.A.E. 4130, S.A.E. 4340 and U.S.S. "Strux" (a modified 98 BV 40).

Since the martensitic structure is capable of attaining the highest tensile strength for a given amount of ductility, our studies have emphasized the development of these steels. In this we have given the highest priority to high strength. Our program also includes several nonmartensitic steels for those places where other properties may be more important than strength.

12% Chromium Steels – As an example of the martensitic steels I would cite the 12% chromium steels. They can be heat treated to a minimum tensile strength of 230,000 psi. at room temperature, and retain a great measure of their strength up to about 900° F.

The 12% Cr steels are resistant to atmospheric corrosion in the sense that they do not lose weight upon long exposure. In time, they discolor or, in some environments, may develop a light film of rust. Mechanical properties of the alloy are not adversely affected by this slight corrosion. (As a matter of fact, *any* of the stainless alloys operating up to 1200° F. will develop a "heat tint".)

Thus, the 12% Cr stainless alloys possess many advantages, including high strength at room and elevated temperatures with good ductility, reproducibility of mechanical properties, air hardenability, and conservation of strategic nickel. Disadvantages include the difficulties of fabricating hard sheets, of heat treating complex structures, and of furnishing hardened sheets to "dead" flatness.

The so-called forced transformation steels, hardened by transformation at low temperature (refrigeration), possess better corrosion resistance and better formability than the 12% Cr steels. They also have the disadvantage of lower strength, poor reproducibility of mechanical properties and high nickel content.

Age Hardenable Steels – Compared to the 12% Cr steels, the transformation age hardenable steels have better formability, particularly in the alloys that remain austenitic after solution annealing. While some of them are now being used extensively, we question if they have as much promise in strengths beyond the 225,000-psi. level as do the steels heat treated by conventional methods. Other disadvantages are the relatively high nickel content of these steels and the problems of reproducibility of mechanical properties.

Perhaps the ideal steel for aircraft would be a true age hardening steel which, when solution annealed, would possess the mechanical char-

*Assistant Manager, Stainless Steels Metallurgy, United States Steel Corp., Pittsburgh. Mr. Gunia emphasized that he was speaking for his firm, and not for the entire steel industry.

acteristics of the annealed austenitic stainless steels and which, by a single aging treatment, could be hardened to the strengths attainable in tempered martensitic steels. Although a considerable amount of research has been conducted in this area, all these goals have not been attained.

Some mention should be made of the cold worked austenitic steels of the 18-8 Cr-Ni family which have long been used successfully in railway passenger cars, truck trailers, and even in aircraft. The best known of these is Type 301. This grade has interesting possibilities for service up to about 650° F. The cold working steels possess the advantage of corrosion resistance, formability, and reproducibility of mechanical properties. The main disadvantages in these steels are their low strength, relatively high nickel content* and the possibility of weakness along welded joints.

Constructional Alloy Steels are also worthy of consideration. Among these are 4130, 4340, U.S.S. "Strux", and U.S.S. "T-1". These steels are quenched and tempered to a martensitic structure having very high strength. Because they rust, their use must be limited to applications where resistance to corrosion is not required or where they can be protected by a suitable coating.

Production Problems

In the development of any steel for a major market, one must ask, "Can it be produced economically and in quantity?" If a new steel cannot be produced under these conditions, there will be continuing problems in availability.

The demands of the rapidly expanding aircraft industry can be served only by high-production facilities. It is difficult to see how any material that can be produced only in small quantities can sustain the dynamic airframe industry.

This problem of producibility is fundamentally a problem for the steelmaker. It is of paramount importance to his customers, for without producibility there can be no availability. In solving this problem of mutual interest the steel producer can go in the right direction only when the aircraft industry defines very precisely the magnitude and nature of its problems.

Many factors enter into producibility, including the compositional limits, hot rolling characteristics, and cold rolling behavior. If chemical limits for new steels are so close that they cannot be met by using the controls now available in the steel plants, then new methods for control must be studied to determine their suitability or we must become resigned to the fact that such new compositions are commercially impractical. A high percentage of rejections not only wastes valuable raw materials but also curtails shipments and delays deliveries — each of which is highly undersirable. If new steels have poor forgeability or hot workability and cannot be converted from ingot to slab and from slab to hot strip, similar waste occurs.

Steelmakers recognize the sound engineering reasons for tolerances closer than the commercial standards for cold rolled strip or sheet. The aircraft industry must recognize, in turn, that the facilities now existing in the steel plants are not capable of working to much closer tolerances. Some airframe builders have requested tolerances about one-fourth the current limits. If these specifications are to be met, it will require a major investment of time and money to engineer and develop new or unusual equipment for hot and cold rolling. The problem of producing "table top" flatness in sheets having tensile strengths above 220,000 psi. must also be solved because the usual type of equipment has not been successful in doing it, up to the present time.

Particularly disheartening has been the tenacious manner in which some members of the airframe industry have insisted that light-gage sheets in widths of 100 in. and up and lengths of 30 to 40 ft. must be made available today. Fortunately, steel sheets 48 in. wide (and to a limited extent somewhat wider) are currently available in lengths up to about 20 ft. We see here an opportunity for the aircraft industry and the steel industry working jointly to arrive at the best practical compromise of properties, producibility, and fabricability.

Whatever weapons system is involved, the optimum basic metal to be used in the aircraft of tomorrow will be common to all. It is most important that a comprehensive, cooperative program be directed toward the determination of that basic metal. The vigor of such a program must be matched by acceleration in the development of the highly specialized production facilities needed to produce these requirements so the product will be available when needed. We believe both programs can go forward together.

*Recently, United States Steel Corp. has developed a nickel-free austenitic stainless steel called U.S.S. "Tenelon" which has mechanical properties equal to and perhaps even better than Type 301.

Tool and Die Steels

*By GEORGE A. ROBERTS**

There has been a great deal of interest during the past year in applying the product of the toolsteel industry to aircraft and guided missiles for both room-temperature and elevated-temperature service. Actually, this results from a new concept in ferrous metallurgy, and I can merely introduce you to its basic elements in the short space available here.

The basic concept to be applied in this instance is the use of materials that have a combination of very important metallurgical properties; essentially they are *(a)* air hardening, *(b)* deep hardening, *(c)* have secondary hardening characteristics, *(d)* have low internal stresses after hardening and tempering to high strength levels, *(e)* permit high tempering temperatures and therefore *(f)* have a stable structure at any given operating temperature up to 1000° F., and *(g)* possess these properties through martensitic hardening and tempering and not through cold work or standard precipitation as ordinarily defined. Metals of this sort, properly balanced in alloy composition to be nonstrategic and of the minimum cost to provide secondary hardening characteristics, will actually produce structural parts of higher properties and higher life expectancy than can be obtained with any of the lower alloy materials which have commonly been applied for these purposes to date, whether we are considering service at room or at somewhat elevated temperatures.

Let us take a quick look at some of the things this concept involves and use as a basis for discussion a 5% chromium, 0.40% carbon, high-strength alloy on which there is a wealth of experience in the toolsteel industry.

It might be interesting to recount a bit of history. This material, to be later described under the trade name "VascoJet 1000", is actually a specific modification of a commonly used die steel for hot working, patented by the Vanadium-Alloys Steel Co. in 1933 and has since been very widely used in the United States. There are other types of hot work tool and die steels which are interesting to the men worrying about aircraft alloys for thermal flight to 1200° F., and which have stable properties at temperatures slightly higher than the range for the 5% chromium material. These will be mentioned at the end; a considerable amount of development work is still required to prove their efficiency because they as yet do not have the ductility generally specified by the aircraft industry. On the other hand, the 5% chromium alloys appear to have sufficient ductility for immediate application.

When tensile strength of the 5% chromium high-strength steel is plotted as a function of hardness, a straight-line relation is found. Furthermore the test results fall within a relatively narrow band irrespective of the mill shapes currently available, ranging from sheet stock 0.025 in. thick up to transverse tests made on 16-in. square billets. (Commercial shapes also include extruded bars and sections.) This band for tensile strength runs from 120,000 to 140,000 psi. ultimate tensile strength at Rockwell C-30 hardness to 300,000 to 320,000 at C-57. Similarly the determined points for tensile yield fall within a narrower scatter band at very close to 80% of the above figures.

Such a chart merely states the well-known fact that the strength of hardenable steels depends upon the hardness, and this in turn largely depends upon the carbon content of the steel itself — a statement which applies to steels heat treated and then tested at 70° F. If this high strength is maintained at elevated temperatures, then the strength-weight ratio of hardenable steels becomes extremely interesting when compared to various nonferrous metals and stainless steel. Toolsteels of the hot work type — and particularly of the 5% chromium type — are in fact superior in strength-weight ratio at elevated temperatures to any known structural material in the range of 400 to 1000° F. as shown in Fig. 4.

It will be noted that the strength-weight ratio is far below the index visualized by Mr. Schapiro of 800,000 at 1200° F., but it is the closest approach that has been reported in this meeting — a level of about 700,000 up to 800° F.

The high strength-weight ratio at elevated

*Vice President — Technology, Vanadium-Alloys Steel Co., Latrobe, Pa.

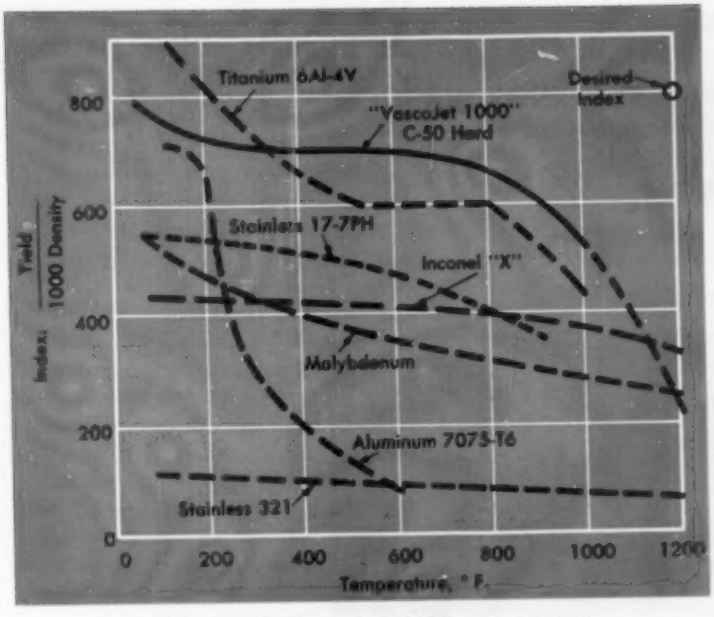


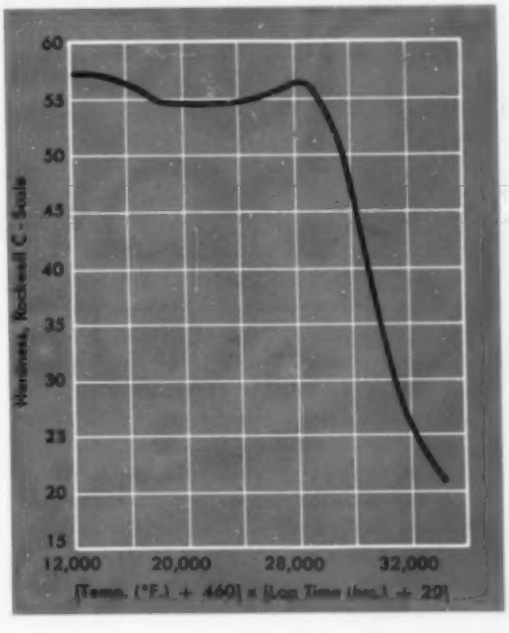
Fig. 4 – Schapiro Index (Yield ÷ Density) of Various Strong Alloys at High Temperatures

temperatures and the satisfactory ratio at room temperature is related to the resistance to softening which is a prime requisite of tool and die steels. The stability of the microconstituents in these steels is such that they can be tempered up to and including 1100° F. and retain strength levels in the range of 220,000 psi. minimum (hardness C-45). Another characteristic property of much interest is that of "secondary hardening" which is well illustrated in the action of 18-4-1 W-Cr-V high speed cutting tools. These are about C-65 hard as quenched, C-62 after tempering at 700° F., and C-65 after tempering at 1050° F. In some alloys this "secondary hardening", or possession of high hardness after an unusually high tempering treatment, is partly lost if the tool is held too long in the drawing furnace. Stability of the hard structure after long exposure at high temperature is consequently important for thermal flight.

To appraise this matter for "VascoJet 1000", Fig. 5 is presented. It permits us to predict the stability of any material in elevated-temperature service, because the horizontal ordinate combines the tempering time and tempering temperature into a single paramenter. Knowing that tempering at one temperature for a certain time has been conducted, the time-temperature relations for stability can then be calculated, and 100-hr. and 1000-hr. operating temperatures can be calculated. For instance, if the alloy is tempered for a total of 5 hr. at 1040° F., 100-hr. stability is achieved at temperatures of up to 950° F.

One outstanding feature of interest to users of high tempering temperatures is the low internal stress level achieved thereby. Internal stresses are also minimized by air hardening. "VascoJet 1000" also has satisfactory ductility in bar, forgings and sheet. Elongation is 10 to 12% when tested at any temperature from 70 to 1100° F. (19% at 1200° F.). Charpy V-notch impact values are equally satisfactory: 28 to 32 ft-lb. when tested at 300 to 1100° F. (60 ft-lb. at 1200° F.). The alloy also has excellent fatigue properties when compared with the standard published values of S.A.E. 4340. Endurance limits

Fig. 5 – Relationship Between Tempering Time and Temperature With Resulting Hardness of 5% Chromium Hot Work Die Steel ("VascoJet 1000") Quenched From 1850° F.



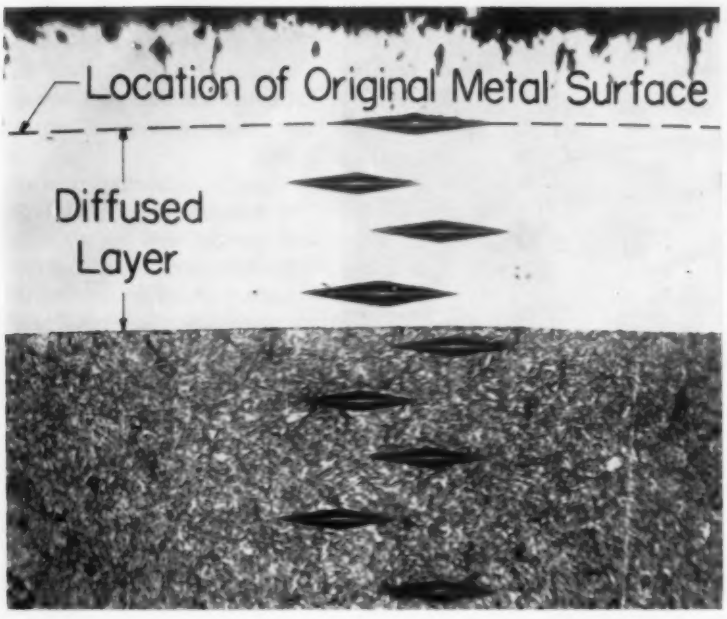


Fig. 6 – Hard Aluminized Layer 0.005 In. Thick on 5% Cr Steel After Hot Dipping and a Combined Diffusion and Hardening Treatment at 1830° F. 300×

by R. R. Moore rotating beam tests on the two alloys heat treated to 260,000 psi. ultimate are 130,000 psi. for the 5% Cr die steel as compared to 95,000 psi. for S.A.E. 4340. Similarly, for higher stresses when fatigue failure occurs at relatively short times – say ±170,000 to ±210,000 psi. – the die steel will endure unharmed at least twice as many alternations of stress as will the S.A.E. 4340.

Corrosion resistance is of great importance for steels in high-temperature service. Certainly the 5% chromium steels have better corrosion resistance than 4340 or any of the lower alloy counterparts, but they may still need additional protection for many operations. In this connection hot dip aluminizing can be done by dipping the 5% chromium steels in a bath of molten aluminum at about 1350° F. The part can then be heat treated and the coating diffused at the same time. The combined diffusion and heat treatment operation is possible because the diffusion temperature and the heat treating temperature are the same, namely 1850° F. Figure 6 shows the microstructure of an aluminum-rich iron layer at the surface about 0.005 in. deep and the usual heat treated microstructure of the 5% chromium steel underneath. As shown by the size of the diamond-like indentations, the iron-aluminum layer is slightly softer than the interior, but tests conducted to date indicate that the tensile properties are relatively unchanged by aluminizing.

It is our belief that further steps in the development and application of tool and die steels for aircraft and missiles must be based on the metallurgical philosophy outlined above. The many small manufacturers of toolsteels are adequately equipped to study such materials which have high secondary hardening characteristics, deep hardenability and resistance to softening on heating. For instance, beyond the 1000° F. capabilities of the 5% chromium steel is a family of materials containing tungsten or molybdenum as the primary element. These alloys do not have as satisfactory properties at room temperature as the 5% chromium steels, especially with regard to ductility, and thus are of more limited interest today. However, several are known and in production which have good strengths and stable microstructures up to 1200° F. One such, known as "WCC", is an alloy containing 4% each of tungsten, chromium and cobalt. It is a combination which should prove satisfactory in service to at least 1100° F., and others containing up to 12% Cr and 12% W may be useful at temperatures up to 1200 or 1300° F.

In the light of the facts above stated it would appear that it is no use to spend more effort and money on minor modifications of S.A.E. 4340 or other low-alloy engineering steels, and that a toolsteel concept has provided a major advance both in room-temperature properties and for materials for aircraft working in the range of 400 to 1200° F.

Superalloys for Airframe Structures

*By F. SIDNEY BADGER**

"Superalloys" is a term which is generally understood to mean refractory metals and their high alloys primarily useful to resist flame and stress. A typical use would be a blade or vane for a gas turbine. Another would be for the contruction of combustion chambers and afterburners. They contain relatively expensive, strategic and dense elements. Any application to the airframe structure must be justified on a strength-to-weight basis, and for temperatures up to 1200° F. (which is much lower than their intended environment in jet engines) they should only be compared with the other metals and alloys which might serve within the top 100° of the range in question, namely 1100 to 1200° F.

As a desirable figure to aim for in future airframes for thermal flight, Mr. Schapiro has suggested an index of 800,000, which represents the ratio of the 0.2% offset yield strength at 1200° F. to the density in lb. per cu.in. This is really setting a high goal. It appears that the best superalloys at present will only reach an index between 150,000 and 340,000 after solution heat treatment and aging. This is shown in Table I, listing Schapiro's index of various commercial superalloys.

There appeared to be a good possibility that a satisfactory balance between cold work and aging might push these figures somewhat higher. Unusually high rupture lives have recently been observed for 10% cold worked and aged Haynes alloy No. 25 at temperatures of 1500 to 2000° F.

Cold working of these sheet materials greatly affects the ductility and would restrict the forming and assembly operations. (This has already been mentioned by Mr. Kostoch.) For example, reduction of area figures when tested at room temperature after various degrees of cold work are as follows for Haynes alloy No. 25†:

Fully annealed	55%	20% cold reduced	27
10% cold reduced	43	50% cold reduced	2
15% cold reduced	33		

Fig. 7 – Schapiro Index (0.2% Yield in Short-Time High-Temperature Test Divided by Density) of Haynes Alloy No. 25† Cold Rolled Various Amounts. Ultimate strength, yield and elongation on samples cold rolled 10% and tested at 1200, 1500 and 1800° F. are noted on the lower curve. Index at 1200° F. for three samples of heavily cold worked sheet after aging 16 hr. at 1380° F. is also noted

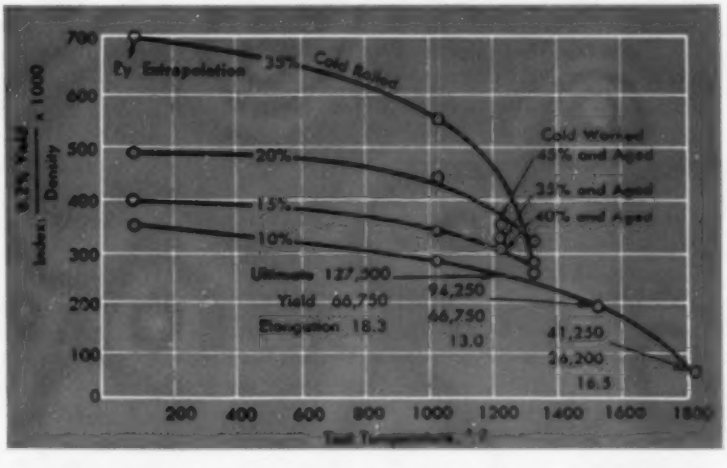


Table I – Index (Yield at 1200° F. Divided by Density) for Selected Alloys

Alloy	Condition	Yield	Density	Index
Nickel-base				
Hastelloy alloy R-235	Annealed Air cooled sheet	100,000	0.296	338,000
Hastelloy alloy C	Annealed sheet	50,000	0.323	155,000
Inconel "X"	Heat treated sheet	82,000	0.300	273,000
M-252	Heat treated bar	83,000	0.298	279,000
Cobalt-base				
Haynes alloy No. 25	Annealed sheet	35,300	0.330	107,000
J-1570	Heat treated bar	85,000	0.305	283,000
Iron-base				
Multimet or N-155	Annealed sheet	37,600	0.296	127,000

*Vice-President and Chief Metallurgist, Haynes Stellite Co., Kokomo, Ind.

†Sometimes called L-605 or A.M.S. 5537. Type composition: 50% Co, 20% Cr, 15% W, 10% Ni, < 2% Fe, 1.5% Mn, 0.5% Si, 0.08% C.

Available figures for "index" of this alloy at various temperatures are shown in Fig. 7. A maximum yield ÷ density index of 440,000 and 560,000 could be obtained at 1000° F. by 20% and 35% cold work respectively, without aging. However, the curves drop rapidly to around 400,000 at 1200° F. Aging the heavily cold worked samples for 16 hr. at 1380° F. lowered the index figures to approximately 320,000 as shown on the curve sheet and in Table II.

Table II – Data for Haynes Alloy No. 25 at 1200° F. (Cold Reduced and Aged 16 Hr. at 1380° F.)

	Reduced 35%	Reduced 40%	Reduced 45%
Ultimate strength	160,100	150,200	146,800
Yield strength	107,300	106,400	116,500
Elongation	8.5	7.3	6.3
Shapiro Index	322,100	319,600	350,000

We now believe that better results would be obtained by aging at 900 to 1200° F. and these tests are under way. Even so, it is doubtful that much more than 20% reduction of this high alloy would be feasible, and still retain useful formability with elongation in tension tests above 15%.

The next approach was to cold work and age a nickel-base alloy containing titanium and aluminum called Hastelloy alloy R-235.* Because of a somewhat lower degree of formability than alloy No. 25, cold work was limited to 10% and 20%. Aging was carried out at 1200° F. for 2 to 16 hr.; results are shown in Fig. 8. The alloy has somewhat lower density than No. 25, high in cobalt and tungsten.

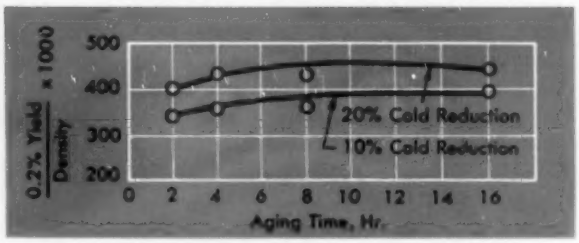


Fig. 8 – Schapiro Index at 1200° F. of Hastelloy Alloy R-235 in Relation to Cold Reduction and Aging Time at 1200° F.*

Figure 8 shows a maximum Y/d index of 450,000 at 1200° F. which was obtained on sheet cold rolled 20% and retaining enough tensile elongation (16%) to be within the range of moderate formability. The uniformity of the index at aging times from 4 to 16 hr. indicates a desired stability of properties.

Other tests have indicated that Hastelloy alloy R-235 maintains high aged properties over a considerable time of exposure to temperatures from 1000 to 1500° F. without over-aging and losing strength.

We now have three problems facing us:

1. How can we raise the Y/d index from 450,000 to 800,000 at 1200° F.? The room-temperature *ultimate* strength divided by density figure for Haynes alloy No. 25 with 50% cold work and aged at 900° F. is 965,000. This material has tensile elongation of 2% and its yield point must be near the ultimate strength on material worked this much. Consequently Mr. Schapiro's index (yield ÷ density) at 70° F. must be somewhat more than 800,000. The question, though, is this: Can a yield ÷ density index of 800,000 *at 1000° F.* be reached in metal aged at 1000° F. and how long can it be maintained? How much of the Y/d index can be retained at 1200° F. (with prior aging at 1200° F.) and how long can it be maintained? Similarly, can Hastelloy alloy R-235 reach this high Y/d figure by more cold work and proper aging?

2. Supposing this high yield index is attained. It will be for metal inevitably having low ductility. Will such material have any possible use by the airframe industry? It is necessary that the airframe industry establish a minimum ductility figure, as well as a maximum strength figure and probably a compromise between the two must be reached. It may well be that high Y/d index sheet can be used for highly specialized applications where formability requirements are at a minimum.

3. Can the superalloys be commercially cold worked on available rolling equipment in the wide widths desired by the aircraft industry and to the degree necessary for the strengths specified? Equipment which we are presently installing at Kokomo will cold roll the materials up to 48-in. widths with a maximum of about 15 to 20% reduction.

Obviously, more guidance is necessary from the airframe industry to reach an acceptable engineering compromise for developing the superalloys for use up to 1200° F.

*Type composition: 65% Ni, 14% Cr, 10% Fe, 5% Mo, 2.5% Ti, 2% Al, 0.1% C, 0.50% Mn max., 0.25% Si max.

Cutting Tools Made of Ceramics

By Our Special Correspondent

Ceramic tool tips are usually made of cemented aluminum oxide, and are most valuable for uninterrupted finishing cuts on cast iron, and for machining hardened alloys or others unduly abrasive to carbide tools. Optimum tool geometry, developed by laboratory research, has been confirmed by production experience. (G17, T6n; SGA-j, 6-20)

In 1951 the Editor of *Metal Progress* concluded an interesting "Critical Point" describing operations at Norton Co. in Worcester, Mass., with a brief note about the use of synthetic corundum (Al_2O_3) for a cutting tool. He wrote:

"Unfortunately no suitable binder has yet been found. When sintered without binder it might be used in a machine shop; it will cut steel cleanly, although not at high speed, but is probably too fragile for general use."

That was six years ago. The large progress in the intervening years may be judged from the fact that a nine-meeting symposium on ceramic tools featured the recent meeting of the American Society of Tool Engineers in Houston, Tex. As pointed out by T. A. Weyher, Commanding General of Army Ordnance, the nonstrategic cutting materials are of growing importance and now include tools made of boron, titanium and silicon carbides as well as aluminum oxide. Progress in the field is, indeed, so rapid that in his prepared remarks Robert F. Rhea of Carborundum Co. quoted 590 surface ft. per min. for 60-min. tool life*, whereas on arrival at the platform he produced data indicating that the figure should be 680 surface ft. per min. under exactly the same set of conditions! Notable improvement of manufacturing had taken place from the time the paper was written until the time it was presented.

He finds that there is a considerable difference between oxide and carbide in cutting tests when running at the same speed, and also a considerable difference in the materials made by various vendors. He emphasized that oxide cutting materials have the same characteristic tool life as carbides – that is, speed decreases the tool life in both categories. Color has no real significance in this respect, but the darker colors are more readily accepted by shop people even though this is no indication of quality.

Russian Experience

A good deal of attention was given to the rather voluminous Russian publications in this field. Evidently these people have been exhaustively investigating aluminum oxide as a cutting material – for example, a very intensive study of the relation of porosity to tool life contained one chart alone which might have taken a complete year for accumulating the data. Apparently, also, this activity bears a fairly close relationship to utility: An American student who visited Russia in 1955 found that wherever he went into a manufacturing plant, he found a great number of ceramics in actual operation.

The Russians have two cutting materials known as Microlite and Thermocorundum which are basically a high-purity aluminum oxide with some form of binder. Published tests compare

*Time: 60 min; material: S.A.E. 4140 at 310 Brinell; feed: 0.0156 in.; depth of cut: 0.050 in.; wear land: 0.030 in.

speed, depth of cut, and feed with carbide tools for total tool life.

They have further studied the relation of the ceramic's thickness to the size of the shim, and find a definite relationship in that, as the ceramic gets thinner, the contact with the shim and the size of the shim become the critical factors. They have further shown that the tool life drops off radically as the number of interrupted cuts increases.

Ceramic tools are ground and finished somewhat differently than they are in America. They recommend a green grit silicon carbide wheel operating at some 2000 surface ft. per min. with a soda solution coolant, followed by lapping with boron or silicon carbide, 220 grit. Compare this with 6000 surface ft. per min. normally recommended in this country with a diamond wheel. Visual inspection is enough, they think; if no cracks are seen at 20 diameters the tool will cut quite well.

Some of the work published in U.S.S.R. on temperatures of carbide and of ceramic (oxide) tools operating under standard conditions has been paralleled by Nathan H. Cook at Massachusetts Institute of Technology. Measured temperatures are about equal to this American work — a conclusion supported by theory and mathematics. Ceramics evidently require slightly less power than an equivalent carbide tool, and the contact area between chip and tool is somewhat greater, but since the thermal conductivity of the ceramic is less, this offsets the reduced energy input.

Tool Geometry

One important thing which Dr. Cook observed has to do with the chip breaker position. In all cutting tests it is usual to measure axial and thrust forces, and both these as well as temperature reached a minimum in some tests varying the position of the chip breaker. Therefore, it might be possible to slow down the tool wear by proper positioning of the chip breaker, even though it wore more rapidly. Wear there is less expensive than at the actual tool tip. It is even possible that a ceramic chip breaker attached to a tool of more conventional material might be worth while, since material cost and the price of preparation of the ceramic chip breaker would be much less than the standard cutting tip insert made from ceramic.

Results of a year's study on lathe tool geometry at Ohio State University were presented by Prof. Harry D. Moore and D. R. Kibbey. To survey the field adequately and rapidly, a Warner & Swasey 1A turret lathe was modified for high-speed research work and a program set up whereby the many variables affecting tool life were tested three at a time at three different levels in all combinations. Among these variables were nose radius, feed, depth of cut, edge lands, and tool geometry. Wear tests in each were tied into the chipping factor, and the probability of error worked out from statistical analysis. Professor Moore concluded that only 1% of the massive fractures occurred after the first ⅛ in. of cut, and 92% of all failures in tools tested without edge lands were by flaking or fracture of the tool. The practical speed range appears to have an upper limit of about 2000 ft. per min. for finish cutting and about 1000 ft. per min. for rough turning (feeds ranging from 0.011 to 0.039 in. and depths of cut up to 0.200 in.). In some tests they were able to cut hot rolled bar stock having scale on the surface, and got from one to eight passes 30 in. long.

The most influential item found by Messrs. Moore and Kibbey was that an edge land on the side cutting edge of the tool is essential for satisfactory tool life. Presence of even the smallest land was more effective than a wide variation in other conditions checked. In addition to this systematic work, speed tests were run at 5000, 10,000, 13,000 and even 16,454 ft. per min. and it was everyone's belief that the latter is a record for American ceramics. (The Russians have reported 12,000 surface ft. per min.*)

Application to Production

This research at Ohio State University was sponsored by the Warner & Swasey Co. and its findings were verified in the machining departments of that firm's Cleveland and New Philadelphia Plants. From this work R. T. Hook and A. O. Haeme cited 11 examples of machining steel and cast iron on turret lathes. The lands recommended by the Ohio State University program were thoroughly checked and found to be a definite improvement on ceramic tool life. In some of these production jobs low tool life was primarily caused by out-of-roundness or presence of heavy scale.

Considerable data were also presented concerning milling with ceramics on several tool holders currently available. Milling of cast iron

*EDITOR'S NOTE: 16,454 ft. per min. is 180 mi. per hr., and this is considerably less than the projectile speeds talked about at the Western Metal Congress in Los Angeles that same week.

Machining Turbine Disks at Chrysler Jet Engine Plant

at speeds of approximately 2500 surface ft. per min. is not beyond the realm of consideration; in fact, as the speeds were increased, tool life and finish appeared to improve. On the other hand, attempts to mill steel were almost complete failures.

Several fairly successful attempts at bonding of ceramics were reported. A few isolated examples of reaming showed again that cast iron could be reamed to size with a good finish and good size control, but steel was very difficult since the reamers wore out rapidly. A conclusion is that ceramic tools have a definite industrial use in finish-turning, but the existing clamped-on tool holders are not adequate for fragile ceramics.

Coolants apparently have no advantage (or disadvantage other than operator inconvenience). There is a very large difference between various makes of American ceramics. Speed ranges of 400 to 1000 surface ft. per min. with feeds of 0.004 to 0.020 in. per revolution and depths of cut from 0.010 to 0.375 in. seem to be practical. It was confirmed that a definite improvement in tool life occurs when the tool has a negative land on the side cutting edge, 30° from the vertical of the workpiece, and ground to a width representing approximately 80% of the feed rate.

Interrupted Cuts and Difficult Jobs

J. F. Allen, factory manager of Cameron Iron Works, Houston, presented the results of work at his plant where ceramic tools were definitely limited to approximately 5% of all jobs because they lack the impact qualities of carbides. In their work they must remove large amounts of metal with uneven amounts of stock and heavy scale. This causes considerable tool failure by breaking rather than by wear. Even so he recommended ceramics for finish cuts if one is aware of their fragile characteristics and takes proper precautions. To reduce troubles from failure of ceramic tips, he uses a carbide tip protector to prevent the chips from hitting the unused portion of the ceramic.

Mr. Allen found that ceramics failed on rough cuts. In several instances he was able to observe the tool tip just prior to failure and he found a large notch opening up in the unused portion of the ceramic – apparently due to chip impact. The carbide tip protector increased tool life, but the ceramic tool is still limited to finish cuts. Ceramic tools are not alone in their brittleness; users of carbides must be aware of their fragile characteristics.

He gave one interesting example of taper turning, using a ceramic tip operating at 440 ft. per min. The work was an alloy of iron, cobalt, and vanadium which had defied previous attempts to machine with carbide. For items like this, of course, ceramics no doubt will have a definite place in the metal cutting field.

Ability to do the almost impossible was stressed by E. J. Weller of General Electric's Metallurgical Products Dept. In a panel discussion he pointed out that many were "missing the boat" by failing to use the ceramic materials for cutting hard metals and alloys and holding the speeds down to the normal range we now use for carbides when cutting soft steels. He cited A.I.S.I. 4340 and 6145 steel parts heat treated to the C-40 to 50 hardness range. Carbide tools will frequently eliminate any grinding on these parts. Considerable savings can be made if the hot hardness of the ceramics is utilized in completely changing the type of finishing operations.

Another suggestion along the same line was made by E. W. Engle of Vascaloy-Ramet Corp. He recommended that metallurgists turn to ceramics when machining alloys which are definitely known to abrade carbide tools. An entire group of such troublesome materials might be cut much more economically with the dense aluminum oxide cutting tools.

Correspondence . . .

Use of Heat Treat Diagrams

BETHLEHEM, PA.

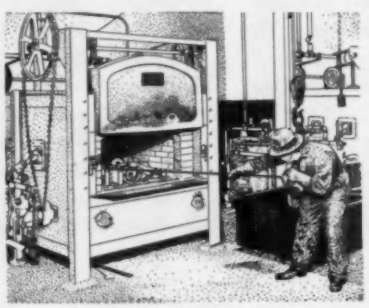
Heat treatment diagrams can be helpful in avoiding some possible difficulties which might result from substituting lean alloy steels for the more highly alloyed grades.

A series of such diagrams has been presented in the preceding three issues of *Metal Progress*, and an article in the March issue (p. 97) described their construction and use in detail. The following example will illustrate the use of the diagram for A.I.S.I. 4024 steel published as a data sheet on p. 96-B of this issue.

Substitution of A.I.S.I. 4024 steel, water quenched, for a carburized part 3½ in. diameter is contemplated for a part which, in the past, has been made of carburizing grades of higher alloy content, oil quenched. The change to a leaner composition and to a water quench would reduce cost of materials and effect operating economies. In making this change, the metallurgist wants to take precautions to prevent quench cracking.

The possibility of cracking can be minimized by removing the carburized part from the quenching bath and tempering it as soon as the temperature of the case is low enough to assure complete hardening. However, the requirement of core strength and toughness must not be overlooked. If the quenched part is put in the tempering furnace before transformation of the core has been completed, the normal transformation of the core may be changed to an extent that would reduce the strength of the core or embrittle it at some vital location. The heat treatment diagram may be used to predict the quenching practice that will prevent this possibility.

Thus the problem is to remove the 3½-in. diameter part from the quenching bath as soon as transformation of the entire part is completed. If it is assumed that transformation to martensite is completed when the steel reaches 250° F., the diagram shows that the 0.9-radius location will be completely transformed after 200 sec. of quenching, and the structure at this point will be less than 50% martensite, balance ferrite, pearlite and bainite. Transformation of the center and midway locations to 95% or more of ferrite and pearlite will be completed in much shorter time (about 60 and 70 sec., respectively). There is an intermediate position between the midway and 0.9-radius position at which it takes 240 sec. to complete the transformation of a small amount of austenite to martensite. But the amount transformed to martensite is small – only 5% – and probably a 200-sec. hold in the quenching medium will suffice to harden the part to its full capabilities.



R. C. HESS and D. J. BLICKWEDE
Physical Metallurgy Div.
Bethlehem Steel Co.

Classification of Metallurgical Literature

NEW YORK CITY

The article by Messrs Kent, Booth and Perry on "Machine Searching of Metallurgical Literature" in February's *Metal Progress* should bring hope to many workers in all fields of engineering who have become aware of the large economic loss and the great inconvenience connected with a systematic search for published facts. The vice-president in charge of research of one of this country's largest corporations told me recently that "if a research project costs less than $100,000 to $200,000 to carry out, it is cheaper to do it than to attempt to find out if the work has been done and reported previously in the literature!" This emphasizes the existence of a situation that may become intolerable. It is a situation that could be greatly improved, and probably even cured, by better abstracts, better classification, and better methods of retrieving the buried and now-lost literature. The A.S.M.-financed work at Western Reserve University described by Mr. Kent and his associates bids fair to lessen greatly the cost of retrieval of published infor-

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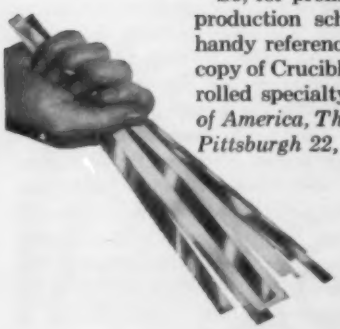

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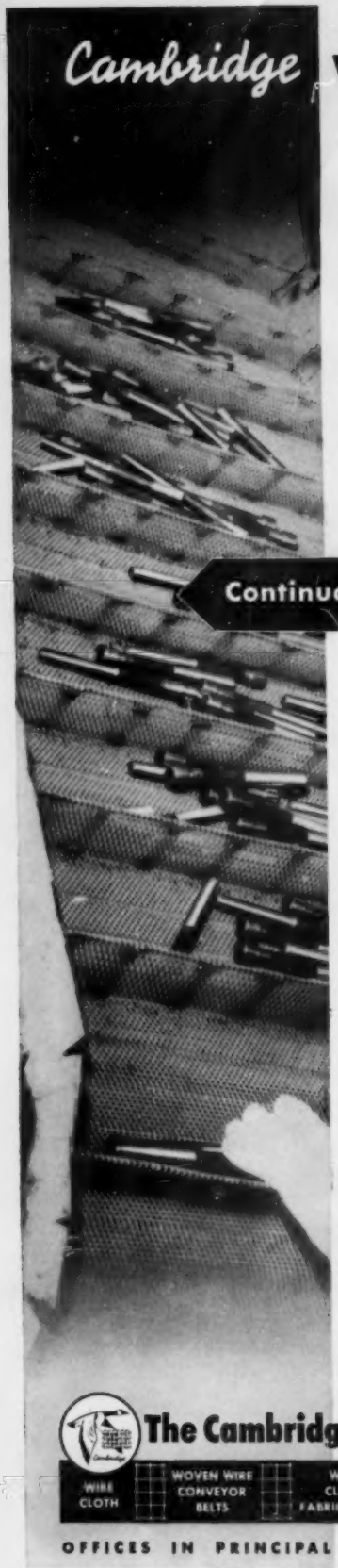

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Classification . . .

mation, *provided* it is adequately abstracted and classified.

This second matter – proper classification – has not been neglected, and I think readers of *Metal Progress* will be glad to know about it.

In 1955 the Board of Trustees of the American Society for Metals appointed a special committee to revise and extend the so-called ASM-SLA Classification of Metallurgical Literature, originally published in 1950. There had been a notable expansion in the arts and sciences of metallurgy. The original classification had proved of outstanding value; numerous metallurgists, engineers and librarians in the United States and abroad have adopted it; the printed edition is exhausted and more than 2,000,000 of the specially printed punched cards are in use. Obviously, such changes as should be made must fit into the original classification – extend it, rather than supplant it.

The committee appointed in May 1955 consisted of 12 people from the several fields of metallurgy; all of them had long personal experience in attempting to solve the problems of classifying the published literature. To complete the work it spent 21 full working days in meetings, and, in addition, each member has devoted many hours to extensive "homework" assigned by the chairman. Attendance has never been below 75% and for many of the meetings it was 100%. The underlying reason for this splendid record is clear – the members of the committee, all thoroughly aware of the over-riding importance of this effort of A.S.M. to bring order out of chaos in at least one important field of engineering, were willing to make any reasonable sacrifice to insure that the job was done effectively and rapidly.

The newly completed classification is now in use in all publications of the American Society for Metals. We believe it will extend the usefulness of the system in those many libraries and data files where it has already been adopted – including some influential organizations in Italy, Germany and England which worked closely with the A.S.M. Committee for the past two years. (There is indeed a strong probabil-

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The terms "Electromet", "Mantemp" and "Union Carbide" are tra le-marks of Union Carbide Corporation.

Classification . . .

ity that the A.S.M. classification could be made an international standard.)

Engineering societies, which spend large sums of money to produce valuable literature, are in general appalled at the difficulties and the cost that seem to be inherent in making even their fairly recent literature available to the engineer who wants to use it. These societies will continue to watch with interest the three-fold attack on the problems – abstracting, classification, and retrieval of metallurgical literature – by the American Society for Metals.

I believe the second-mentioned requisite, classification, has now been solved in an adequate manner.

FRANK T. SISCO,
Director, Engineering Foundation
Chairman, Literature
Classification Committee

EDITOR'S NOTE – Members of Mr. Sisco's committee were:

Edwin A. Clapp, Electro Metallurgical Co.

Frederick Forscher, Westinghouse Electric Corp. (Now with Nuclear Materials and Equipment Corp.)

Laurence S. Foster, Watertown Arsenal

C. D. Gull, National Academy of Sciences

Worthy W. Howell, Chemical Abstracts Service

Irving H. Jenks, Aluminium Laboratories, Ltd.

Allen Kent, Western Reserve University

Daniel J. Maykuth, Battelle Memorial Institute

E. C. Wallace, New York Air Brake Co.

Frederica M. Weitlauf, Inland Steel Co.

Marjorie R. Hyslop, American Society for Metals, *Secretary*

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Russian Metallurgy

CHICAGO

I was interested in reading Lee Wilson's story about Soviet Steel Mills in the January issue of *Metal Progress*, and it is refreshing to compare up-to-the-minute first-hand impressions with my own memories of things seen a decade ago, or powers of visualization from book and journal data. In this connection, a few remarks may be in order.

I should think that the German strip mill at Magnitogorsk mentioned by Mr. Wilson is in all probability the dismantled Dinslaken mill, presented to the Russians by their American and British friends-in-arms after World War II.

The CKM-3 machine builder is undoubtedly the "Staro-Kramatorkyi Machinostroyitelnyi Zavod" in Kramatorsk, a city in the Donez Basin. The name means "Old Kramatorsk Machine Building Works" as distinct from the New Kramatorsk Works built in the same city in Soviet times (1932 to 1935). What Wilson saw on the tabs was "CKM3", equivalent to our "SKMZ", their C being our S and their 3 being our Z.

After reading on p. 118 about the tennis shoes and slippers worn by workers, I thought that living standards have changed very little in Russia since 1939 to 1945, when I was there. Leather is still scarce

Benrus plant engineer says:
"ARMOUR technicians helped solve our ammonia problems at Benrus"
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Plant Engineer
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Many design problems—including even heavier parts—can be solved with malleable iron when you understand its widely versatile possibilities. Call a malleable foundry for information and suggestions, or write to the Malleable Founders' Society.

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1800 Union Commerce Building Cleveland 14, Ohio

Russian Metallurgy . . .

and expensive so the common folks wear canvas and synthetic rubber footwear. In the coal mining regions the people probably still wear heavy rubber slippers similar to those used by Dutch countrywomen (at least in the old paintings).

Mr. Wilson's remarks on labor conditions also sound very familiar. He mentions the "astounding number of women working in mills"; also that they are using a lot more labor on most jobs than we do in America, even though everyone seemed to be working at a good rate of speed under efficient supervision.

The net result of this combination of a lot of hardworking peons coupled with high-order supervisors is clearly stated in a brochure printed in Moscow in November, 1956, and written by Yu. E. Maksarev, deputy chairman, New Technology Committee of the Council of Ministers of the USSR. He says that "at present, the production cost of rolled products is two to three times higher than in the United States. At times this leads to extraordinary situations. For instance, ball bearing races can be conveniently made from tubing; yet the Ministry of Ferrous Metallurgy supplies these tubes at such prices that it is cheaper to turn the race rings from solid bars." A similar statement was also made regarding the production cost of crude steel.

N. H. Polakowski
Department of
Metallurgical Engineering
Illinois Institute of Technology

Titanium Alloy Classification

Columbus, Ohio

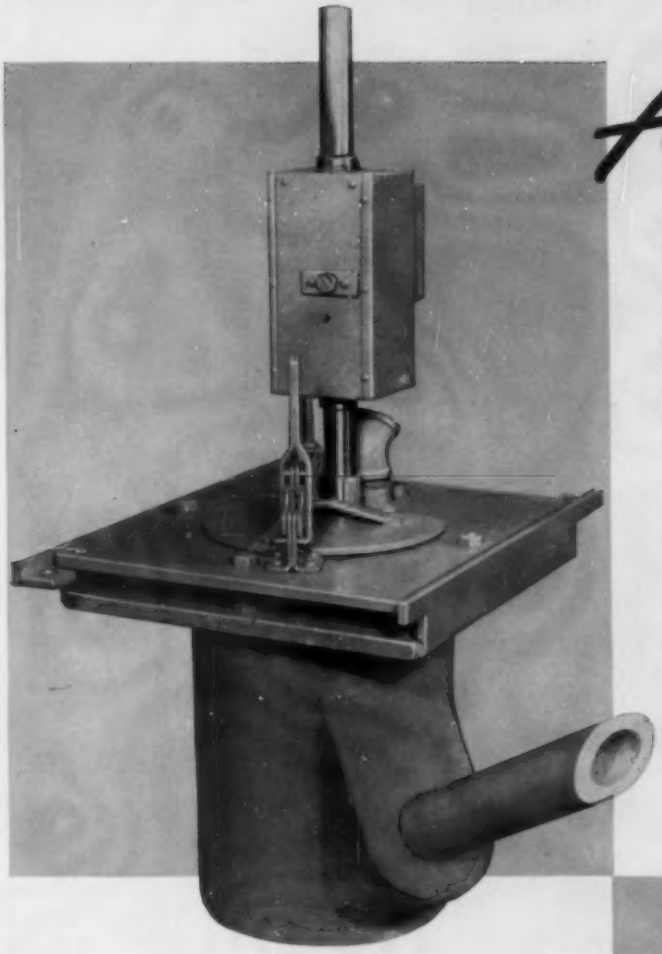
The new titanium alloy nomenclature system proposed by the Titanium Metals Corp. of America and presented by T. W. Lippert as a data sheet in the January issue of *Metal Progress*, p. 96-B, is quite ingenious.

However, the principal failing of this system is that it will not accommodate alloys containing more than a 10% total of either alpha or beta stabilizing elements. Several such

Automatic casting of Aluminum *now practical*

with *New* LINDBERG-FISHER Autoladle

We call it "LITTLE JOE"



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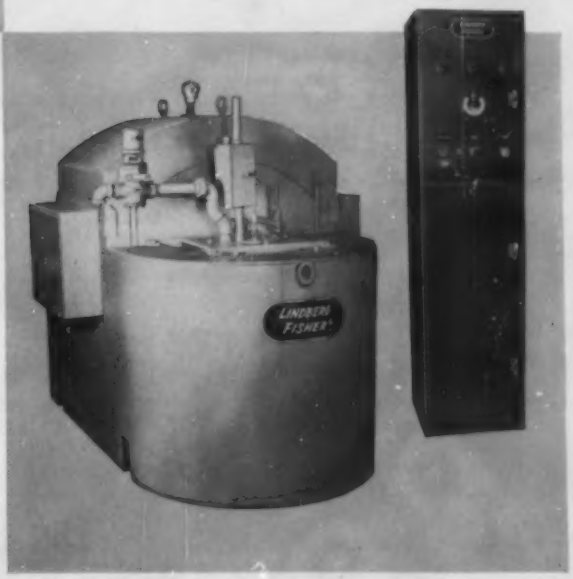
- No variation of size of shot due to metal level changes.
- Composed of special refractory materials so arranged that ladled metal cannot come in contact with any metal.



At the right, "Little Joe" is shown installed in a Lindberg-Fisher electric resistance aluminum holding furnace. With it is the panel cubicle and controls which is supplied completely assembled and wired. For complete information on the Autoladle get in touch with your nearest Lindberg Field Representative (See your classified phone book) or write us direct.

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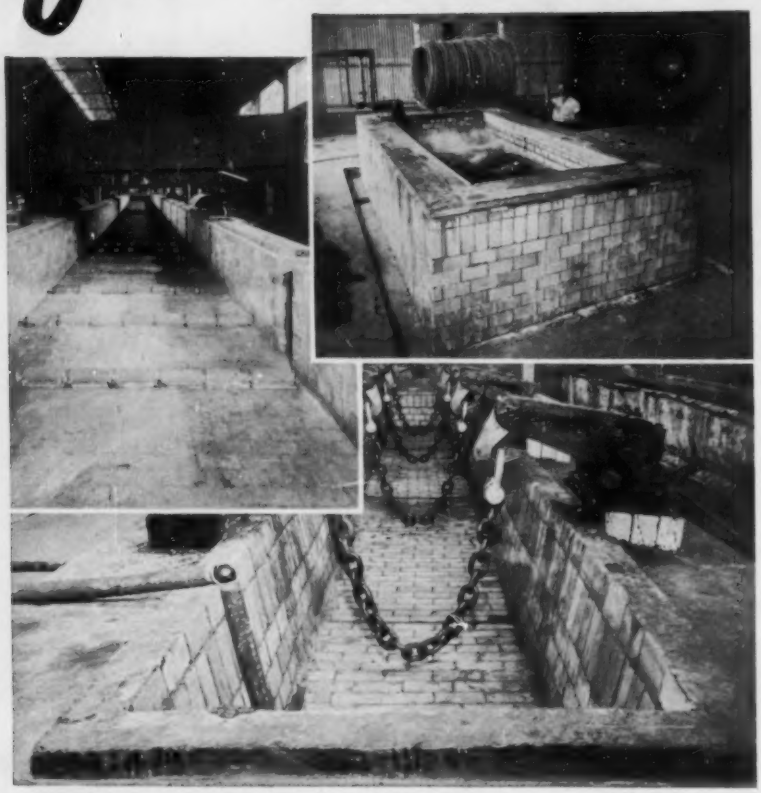
They Looked... and Chose

Atlas FOR THEIR CORROSION-PROOF PICKLE TANK INSTALLATIONS



These modern processors of metals pictured above chose Atlas corrosion-proof cements and know-how for the construction of their pickling installations. Their decision was based on Atlas's long recognized experience in the field of Corrosion-Proof construction. From on-the-spot technical advice through complete installation facilities, Atlas can carry the job from beginning to end.

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Titanium Alloys . . .

commercial alloys (Ti - 12.5 Sn - 3 Al and Ti - 16 V - 2.5 Al) already exist. Also, the supposition that aluminum is the only alpha-soluble metal that needs identification is arbitrary.

Another weakness of this system lies in the need for a knowledge of the combined oxygen and nitrogen content of the various alloys. So far as we know, none of the alloy producers have yet set a firm limit for oxygen in their commercial materials. Indeed, because of the difficulties involved in analysis, the oxygen content of commercial products is only determined at infrequent intervals.

DANIEL J. MAYKUTH
R. I. JAFFEE
Battelle Memorial Institute

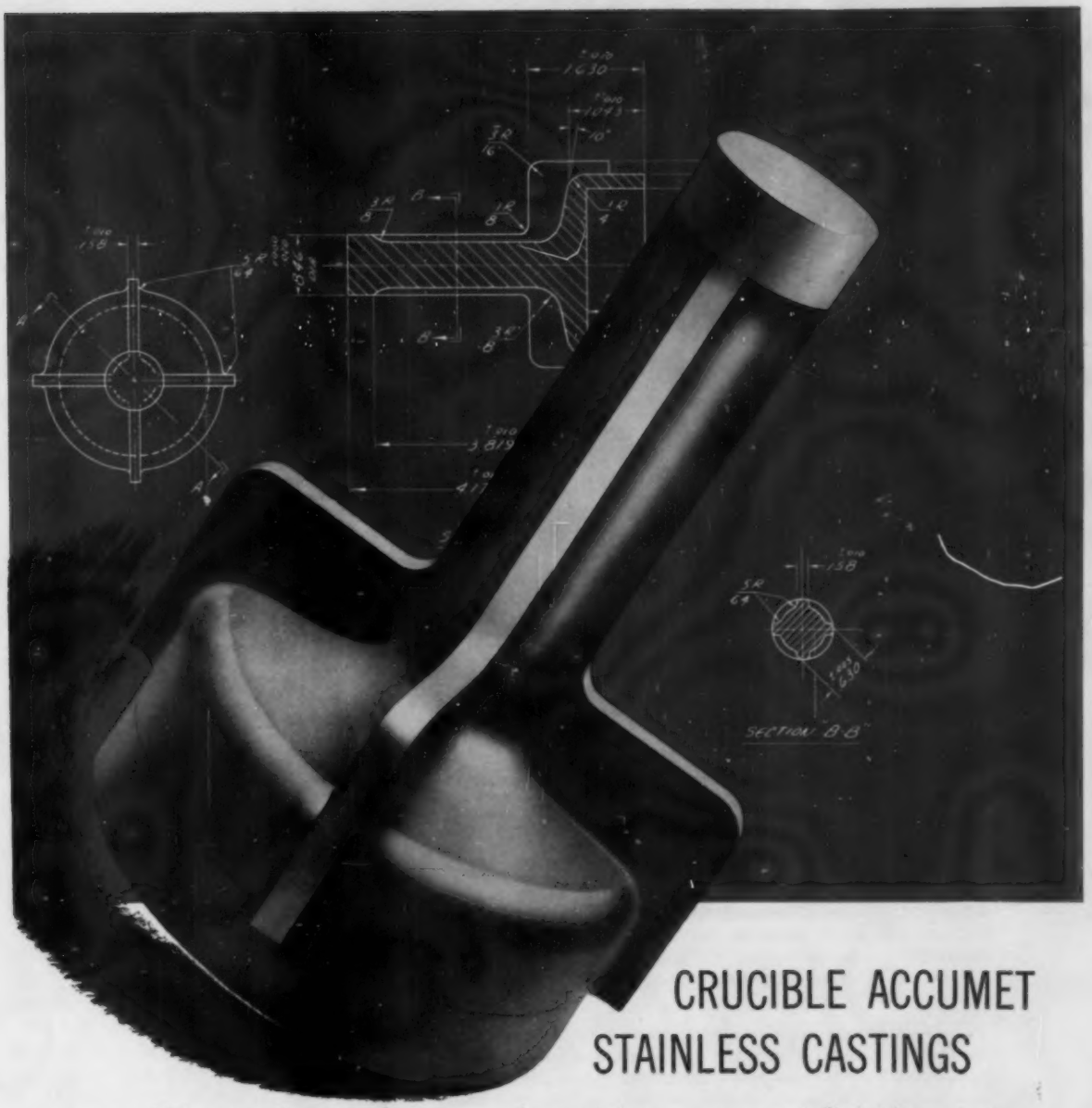
NEW YORK CITY

It is admitted that the major weakness of this nomenclature system is its inability to accommodate, or accurately identify, an analysis having more than 10% alpha or beta stabilizing elements. To devise a nomenclature capable of spreading over an extremely broad spectrum demands something either exceedingly complex or so crude as hardly to be informative.

As a matter of fact, there is reasonable doubt as to whether any commercial alloys will have higher than 10% of either alpha or beta stabilizing elements. Messrs. Maykuth and Jaffee state that two such commercial alloys exist (12.5 Sn - 3 Al, and 16 V - 2.5 Al.) I would consider these to be hopefully experimental. If and when an alloy with more than 10% alpha or beta stabilizing elements wins solid commercial recognition, then possibly the nomenclature system could be suitably modified. Winning such commercial acceptance is usually a long and difficult process, and many experimental alloys fall by the wayside.

I do not understand the comment that aluminum is the only alpha-soluble metal identified. Other elements are accommodated by the third digit.

The fact that the system requires a knowledge of the combined oxygen and nitrogen content is considered a strength rather than a weakness. Some specifications already limit oxygen, and any producer must have



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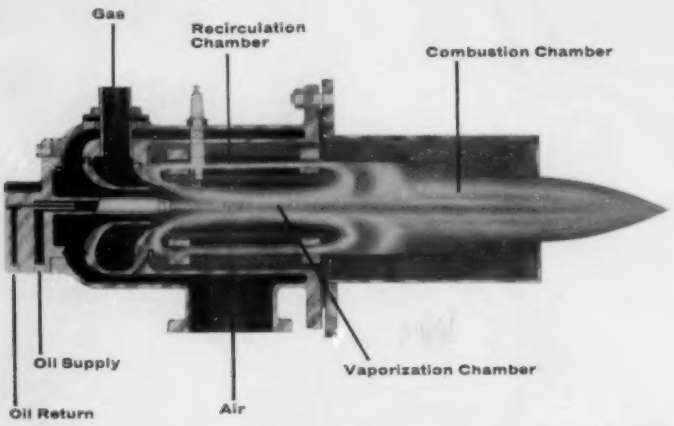

This versatile burner retains its high velocity combustion characteristics whether the fuel used is distillate oil or gas. The flame is short and non-luminous with an exit velocity of between 300 and 500 ft/sec. On either fuel, 85% of combustion takes place within the burner itself and the flame length seldom exceeds 1 ft. Switching fuels is simple and the burner need not be shut off during the changeover.

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WRITE FOR BULLETIN #109

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REPRESENTATIVES IN PRINCIPAL CITIES

Titanium Alloys . . .

fairly good knowledge of oxygen and nitrogen content. The need for continued improvement in limiting oxygen and nitrogen contents is universally recognized. Most producers shy away from oxygen analysis as a routine acceptance test because of the time required and high cost, and even more so because outside laboratories often are not skilled enough to run check tests.

However, in-plant oxygen tests are, I'm sure, far more frequent than Mr. Maykuth and Mr. Jaffee indicate, and as procedures continue to improve, accurate oxygen control will be a routine production tool.

T. W. Lippert
Manager of Sales and
Technical Service
Titanium Metals Corp. of America

Hot Ductility Characteristics of Welded Austenitic Steel Pipe

Jersey City, N.J.

The article by Soldan and Mayne entitled "Cracking Tendency in Heavy High-Temperature Steam Piping" (*Metal Progress*, March 1957, p. 78), emphasizing the importance of hot ductility, is an important contribution to the rapidly increasing knowledge of the high-temperature behavior of austenitic piping materials. It is the first presentation to use the weld-thermal cycle hot ductility test (originated by E. A. Nippes) in the analysis of the behavior of steels in steam power plant service. Their data on the serious but relatively small degree of cracking in service of heavy-walled Type 347 piping welded with electrodes of generally matching deposit composition, is a most useful addition to the literature. Their encouraging results in welding with the 16-8-2 Cr-Ni-Mo electrode (developed by Carpenter and Wylie) indicate that the control of cracking in fabrication of heavy-walled austenitic weld joints is imminent. Of great significance is the fact that a large number of 16-8-2 Cr-Ni-Mo deposits, both as repair welds and as original welds used singly in full

Q

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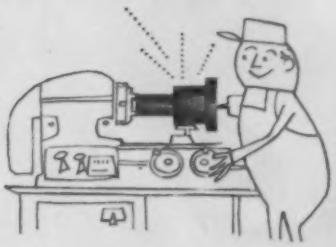

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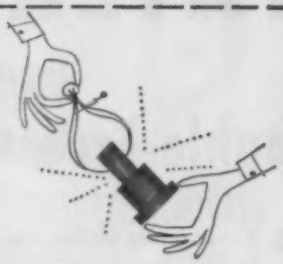

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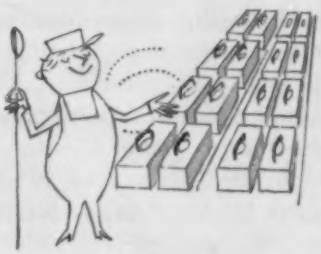

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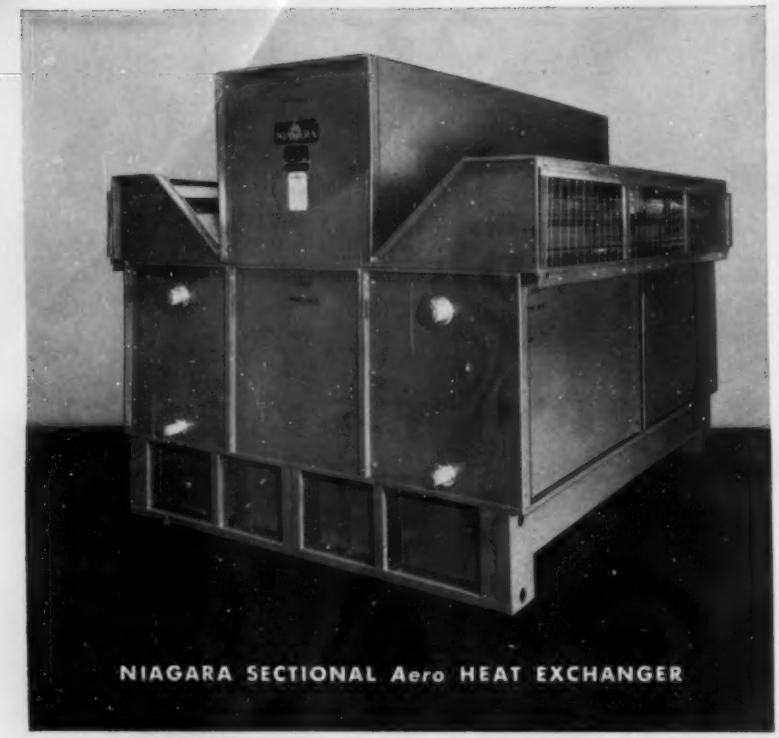
6-61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Hot Ductility . . .

butt joints, have now been in continuous service for many thousands of hours without showing any adverse effects.

One point brought out by the authors is of prime importance. They state that "Considerable time at temperature in service was required for the cracks to propagate through the pipe wall, which probably accounts for the fact that no catastrophic failures have occurred in service." The evidence appears to be strong that under steam power plant conditions crack propagation is a cyclic, stress-rupture type of phenomenon, requiring considerably more time and higher energy levels than in the brittle type of behavior experienced in many plain low-carbon steels at certain ambient and subzero temperatures. The consequence of the type of behavior reported by Soldan and Mayne is that time is thus available for periodic surface inspections to be made.

The authors state that they are considering a study of the effects of the four variables – grain size, melting practice, forging practice and chemical composition including minor elements. These general variables and a number of other factors were also the subject of a paper given by the writer before the A.S.M.E. annual meeting in 1956. This proposed approach is indeed necessary in order to obtain a fundamental solution to the problem. But it is a big task, and A. W. Rankin of General Electric Co., in discussing the writer's proposed approach, has urged the forming of an industry-wide group having sufficient funds to perform the investigation.

It appears probable that the greatest benefits will result from study of the effects of variables in the melting operation and the control of chemical composition. In this approach the experience of austenitic stainless steel producers, in cooperation with metallurgical personnel of piping fabricator and steam power plants, would be of great value in setting up a study program. It will be remembered that the graphitization effects encountered by the steam power industry in carbon-molybdenum steel were found to be strongly related to melting practice (aluminum deoxi-

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CRUCIBLE first name in special purpose steels

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Hot Ductility . . .

dation), with ultimate control resulting from a change in chemical composition – that is, the addition of chromium. Similarly, it has been shown that brittle behavior of low-carbon steels is related to melting practice and control of composition. It should not be construed from the above that melting practice is believed to be the only factor which should be considered; however, it appears highly probable that the melting operation plays a major role.

Another approach to the problem would be to obtain commercial austenitic steels from a number of producers of these materials, in the United States and abroad, particularly in England and Germany. Results of hot ductility tests on such compositions could be correlated with melting practices of the producers, with the ultimate aim of controlling hot ductility characteristics.

In the steam power industry the behavior of austenitic steels for main steam piping, based on experience to date, is essentially a welded joint problem occurring in the heat affected zone. Since the heat affected region is nearly always coarse grained, and large-grained structures are inherently more prone to hot shortness, a need exists for the development of austenitic steels which are more sluggish to grain coarsening in the very short time periods to which zones in parent metal adjacent to the weld metal are subjected in welding. The addition of elements such as cerium, the oxides of which are reported to produce smaller grains in cast materials by providing more nuclei and other grain restraining elements, would appear worthy of study.

The company with which the writer is associated is currently fabricating heavy-walled main steam piping of Type 316 austenitic steel for five modern high-temperature stations. One of the five will operate under most severe service conditions – 5600 psi. at 1200° F. For all these piping materials data are being collected regarding melting practice, grain size and metallographic structure and, in addition, weld-thermal cycle hot ductility tests on actual production materials. The results will ultimately be related to behavior of materials in fabrication and service.

H. S. Blumberg
Consulting Metallurgist
M. W. Kellogg Co.
Schenectady, N.Y.

As Messrs. Soldan and Mayne have pointed out, there appears to be a good correlation between the results of the Rensselaer hot ductility test and the tendency toward cracking during welding in the austenitic steels. Since this test simulates the thermal cycle to which base metals are subjected during the welding process, and provides a means of determining ductility during the cycle, it is difficult to imagine a more representative test to determine this aspect of weldability. The General Electric Co. provided the initial financial support and direction in 1952 to modifications of the Rensselaer equipment necessary to conduct this test, and have now installed similar equipment in our own laboratories. We intend to use this equip-

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following page shows floor plans for both job lot or continuous installations

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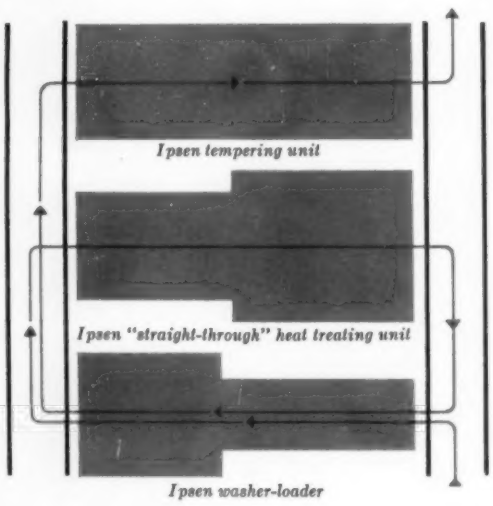

This arrangement includes an Ipsen Washer unit, an automatic "straight-through" heat treating unit, and a tempering unit installed side by side. Two transfer cars operate on crosstracks which connect the three units at both the charge and discharge ends.

Loaded work tray enters the washer . . . emerges from the discharge end to the transfer car which moves the tray to the charging end of the heat treating unit. Tray then enters the work chamber of the heat treating unit . . . passes from the discharge end to the transfer car, then back to and through the washer. The next transfer is into the tempering unit, and the work is ready for the next step of manufacture.

Automatic control of time, temperature, and atmosphere . . . plus the "straight-through" job lot processing features of Ipsen automatic heat treating units offer definite advantages over conventional "in-and-out" job lot type equipment.

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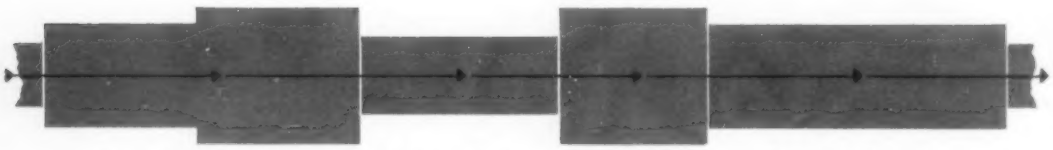

This is a completely automated installation. Special Ipsen-designed mechanisms receive the loaded work trays, move them into the furnace work chamber . . . later transfer them from the discharge end of the heat treating unit to a washer . . . then from the washer to the tempering unit . . . and finally out of the tempering unit to the next processing point.

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Hot Ductility . . .

ment not only as a means of checking production materials prior to shop fabrication, but also as a research tool in an endeavor to determine the basic factors which define the hot ductility of the austenitic steels and superalloys.

The authors attribute the superior performance of the 16-8-2 electrode in welding materials having poor hot ductility to the superior ductility of this electrode. In our opinion, however, the lower yield strength of the 16-8-2 electrode at the temperatures at which base materials exhibit low ductility is more responsible for its lesser tendency to cause cracking in the base metal. In other words, when the weld metal contracts on cooling, the strain associated with this contraction occurs in the weld material rather than in the low-ductility heat affected zone. The ductility of the 16-8-2 weld metal is undoubtedly important in determining the resistance to cracking in the weld metal itself. Since the reasons for the cracking which has been encountered adjacent to welds in service have not been completely explained, and there is considerable disagreement on the various mechanisms proposed, the relative roles of the hot ductility test and the 16-8-2 electrode have not been well defined.

We look forward to additional data correlating hot ductility tests with service performance as reported by the authors, and to service performance data on the many 16-8-2 welds now in service to which no post-weld heat treatment has been applied. There is no question that the tendency toward cracking in service varies markedly from one heat of steel to another and that for a given heat of steel, welds made with the 16-8-2 electrode with no post-weld heat treatment are less prone to cracking than non-heat treated Type 347 welds. At the present state of knowledge, however, we believe that a post-weld heat treatment of austenitic welds is still advisable to insure maximum reliability.

A. W. RANKIN and R. M. CURRAN,
Large Steam Turbine-Generator Department
General Electric Co.

(Additional comments on this article are contained on p. 132)

Driver-Harris Announces Major Advance in Pyrometry!

New #242-33 Thermocouple* for Reducing Atmospheres Maintains Calibration Through a Greatly Extended Life

This new Driver-Harris Thermocouple was developed primarily to withstand industrial reducing atmospheres at high temperatures and thereby to end the danger of runaway furnaces and ruined charges.

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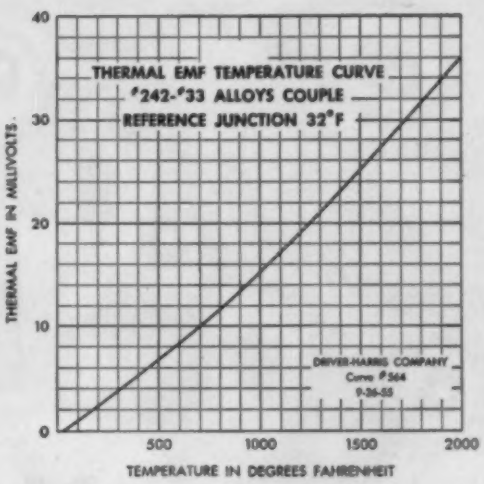
Positive Leg (No. 242 Alloy)	Negative Leg (No. 33 Alloy)
80/20 Ni-Cr + Cb	3% Si-Ni



Although the thermal-emf response of this thermocouple is lower than the conventional thermocouple now in use, the slope of its temperature-emf curve is virtually parallel in the higher ranges of temperature in which both couples are designed to be used. Thus, the thermal-emf sensitivities are equivalent in the higher temperature ranges.

Tested against the conventional thermocouple in an atmosphere of the following nominal composition: CO...10%; CO_2...5%; CH_4...1%; H_2...16%; O_2...Nil; N_2...Balance (best for accelerating green-rot attack), exposure after 212 hours showed *only +0.13 mv. drift for the D-H thermocouple, and −7.54 mv. for the conventional thermocouple.*

When the thermal-emf of the conventional thermocouple *drops*, as in a reducing atmosphere such as this, the working temperature of the furnace controlled by it *rises*. However, when a #242-33 couple is used under the same conditions the thermal-emf remains substantially constant. This means that a furnace controlled with the new D-H thermocouple *cannot overheat and ruin charges.*

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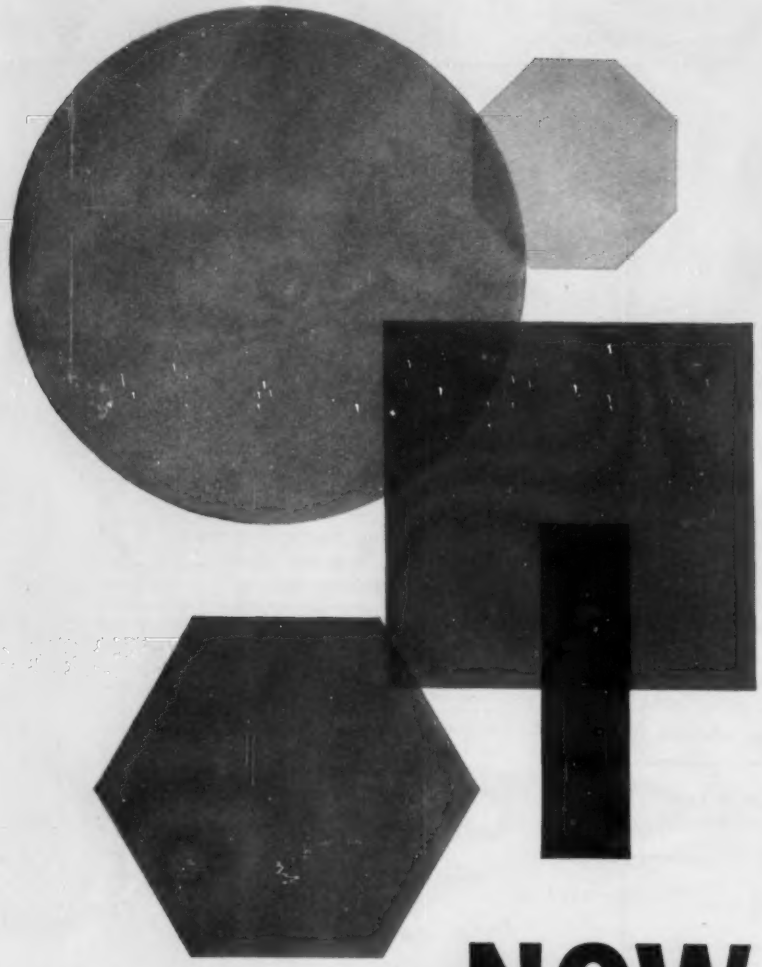

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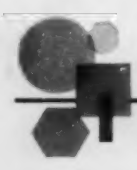

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Hot Ductility . . .

BARBERTON, OHIO

The authors have presented a very useful analysis of service failures and some of the measures which have been taken to better define the basic difficulties which have arisen in the welding of Type 347 stainless steels. We are happy to be associated with the authors in this development program, and have followed it with great interest.

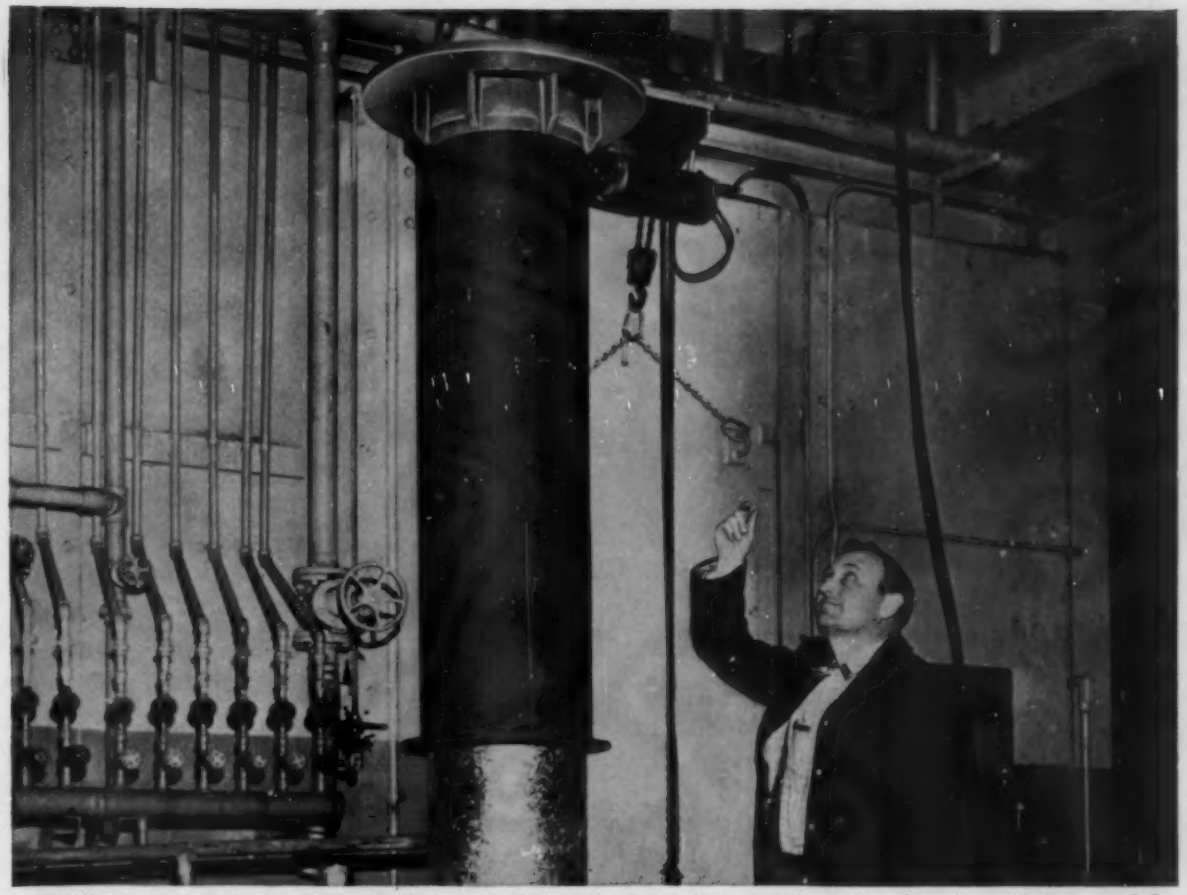
The Croloy 16-8-2 material which was mentioned in the report was developed by the Babcock & Wilcox Co. in cooperation with U.S. Navy Bureau of Ships Code 537. The excellent properties described by the authors have corroborated many of the thoughts which were used in the development of this material, particularly with reference to importance of ductility of the weld metal.

We expect that the final answer to the problem of hot cracking of weldments will not be merely a change of weld deposits. Since the basic problems are apparently associated with Type 347 steels, the obvious conclusion is that a change in wrought material should also be made. For this reason we have developed the 16-8-2 wrought material which was also mentioned in the paper. This material will be subject to many types of tests including the Rensselaer hot ductility test, the stress relaxation test at General Electric, and the creep and stress-rupture tests at the Babcock & Wilcox Co. In addition, Mr. Soldan is planning to place a section of pipe of this material in a cyclic heating test vessel which has been used for many years. The results of all of these tests should indicate whether this material is a substantial improvement over Type 347 or Type 316 for high-temperature, high-pressure steel pipe.

R. D. WYLIE
Chief Metallurgist
Quality Control Dept.
Babcock & Wilcox Co.

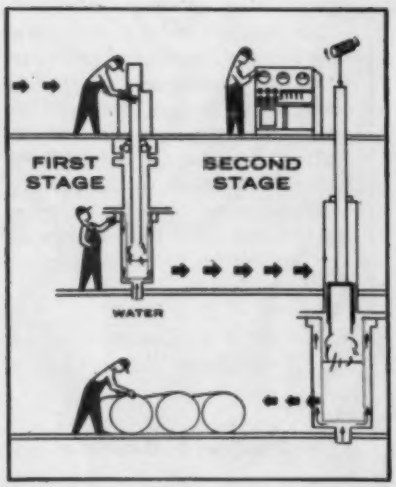
LESTER, PA. . .

Thanks are due to authors Soldan and Mayne for making their observations and correlations available in such well-organized form. Continued effort of this type will lead to rapid advancement in the technology of austenitic steel welding, particularly



STRIPPING titanium ingot from crucible fabricated from Anaconda large-diameter seamless copper tube. During melting, the crucible is water cooled.

How Copper helps make superior Titanium Ingots



SPONGE TITANIUM pressed into electrodes is melted in the first-stage arc furnace, forming ingots. Several such ingots are welded together and used as an electrode in the second melting. Double melting gives homogeneous, uniform ingots. A vacuum in the crucible assures low hydrogen content.

Titanium and titanium-alloy ingots that are homogeneous and have low carbon and hydrogen content are difficult to produce. Mallory-Sharon Titanium Corp. of Niles, Ohio, however, originated the double-melting process, "Method S," for production, which does the job.

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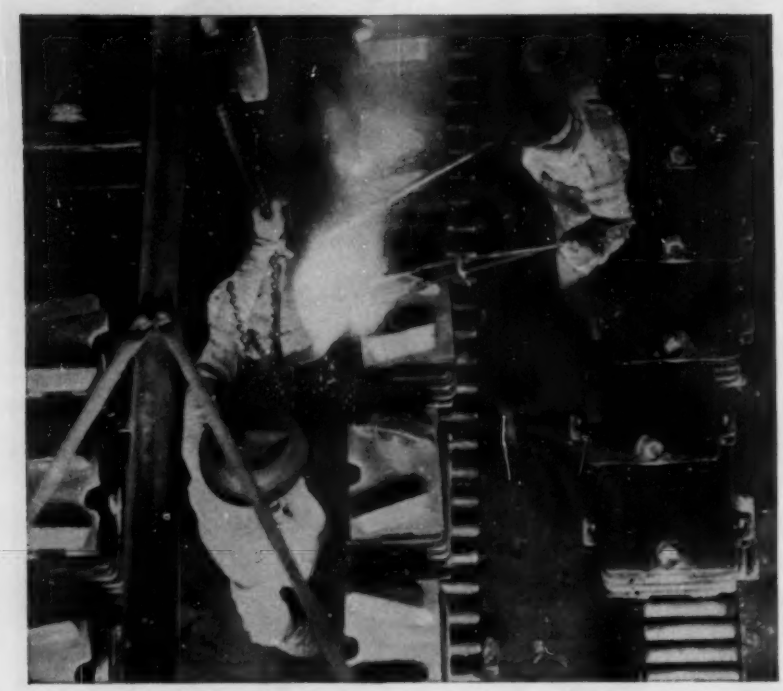

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Hot Ductility . . .

in the high-temperature power piping field.

We agree with the authors that hot ductility requirements should be made a matter of specification for high-temperature austenitic piping if it continues to appear as important as indicated by the data in this article.

We plan to make hot ductility tests from material representative of all welding ends on the inlet piping on three high-temperature turbines which we are now building. One of these machines will operate with inlet steam at 5000 psi. and 1200° F. The other two units will operate with inlet steam at 2350 psi. and 1100° F. Governor valves, throttle valves, weld-ells, and U-bends will be tested as well as the pipe itself. It is also our intention to make creep-rupture tests from material adjacent to the hot ductility tests so that correlation with strength as well as with fabrication and weldability can be made.

With regard to the authors' proposal that hot ductility requirements be incorporated in A.S.T.M. Specification A-376 for high-temperature piping, we wrote such a requirement into our purchasing specifications for the three units mentioned above. However, because of the producers' lack of knowledge of melting and forging factors which affect hot ductility, acceptance of this requirement by our suppliers has not been universal.

The authors' findings of a difference between longitudinal and transverse hot ductility and its possible effect on the integrity of support lug attachment welds is of interest. Although we did not have definite data to support our stand, we have avoided the use of welded support brackets and other welded appendages on our austenitic inlet pipes currently being built.

E. A. Fox

J. D. Conrad

Westinghouse Electric Corp.

Newark, N.J.

Author's Reply

The opportunity offered by Babcock & Wilcox Co. (mentioned in Mr. Wylie's letter) to install a piece of wrought 16-8-2 pipe in the cyclic

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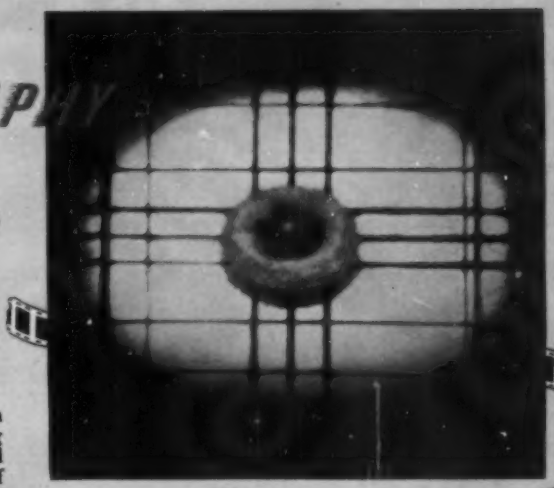

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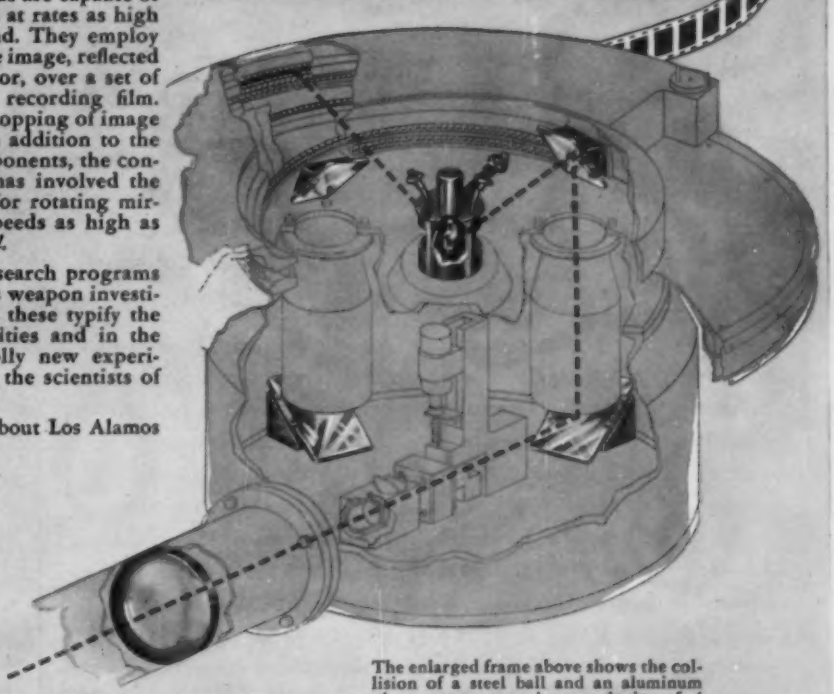

The enlarged frame above shows the collision of a steel ball and an aluminum plate at an approximate velocity of 4 millimeters/microsecond, illustrative of studies of interaction of metals at high impact velocity. The cutaway drawing shows some of the features of one of the Laboratory's high speed framing cameras.

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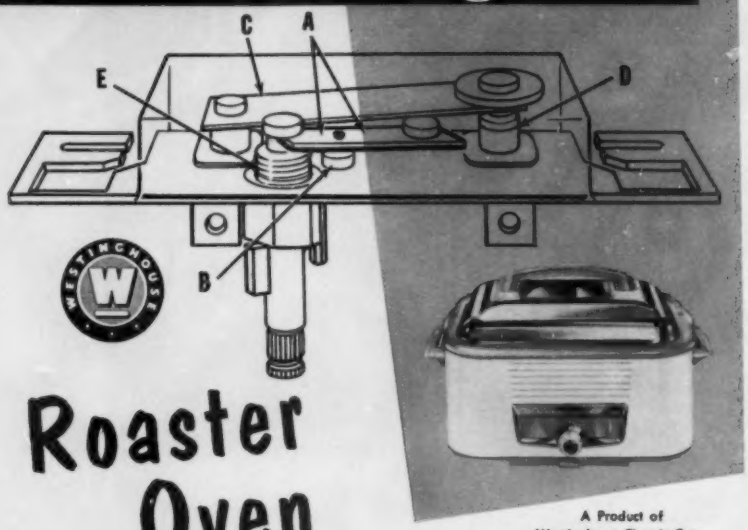
HOW CHACE THERMOSTATIC BIMETAL CONTROLS THE Westinghouse



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Hot Ductility . . .

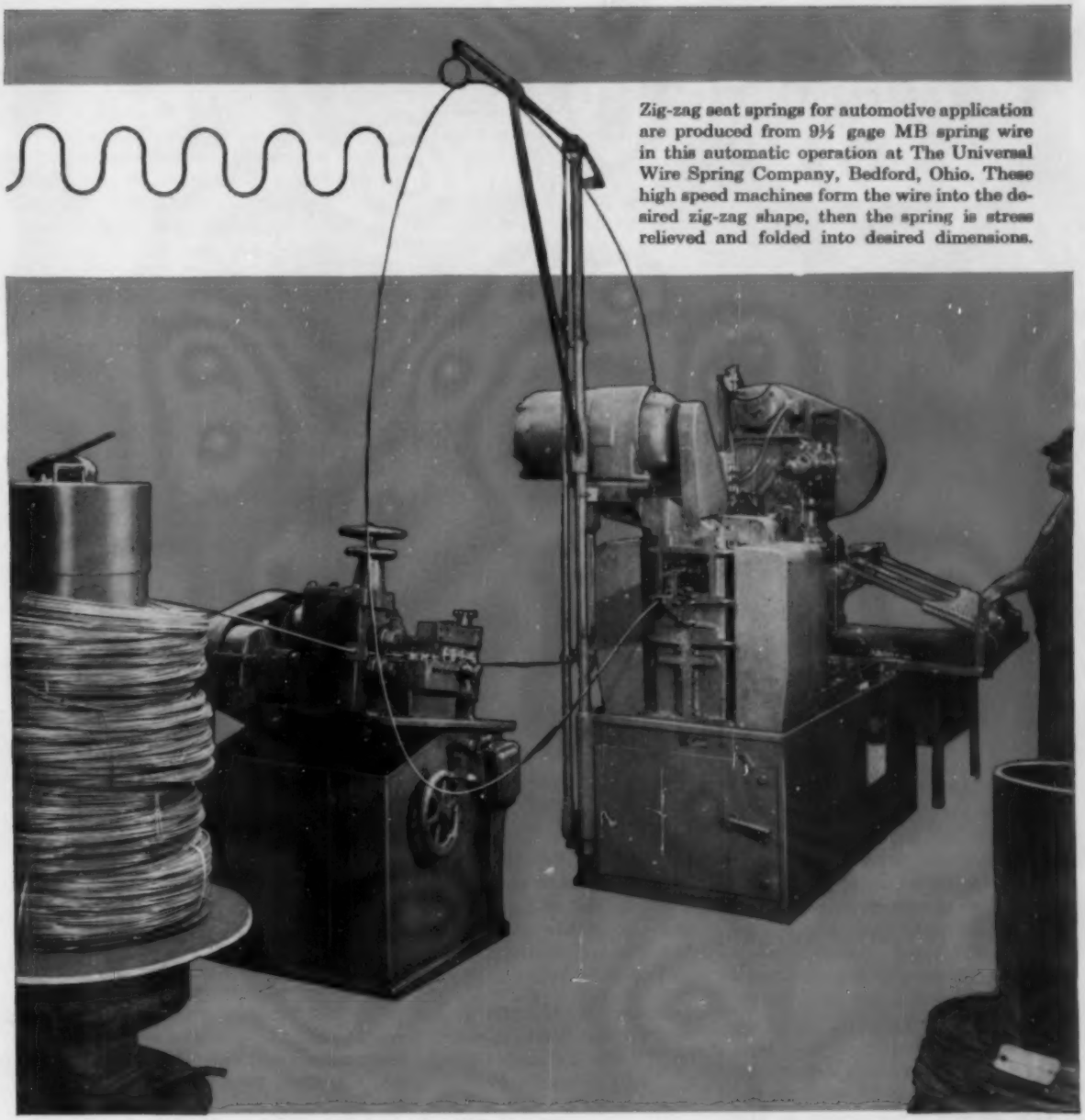
heating test being conducted by Public Service Electric and Gas Co., in order to duplicate high-temperature steam service performance, is appreciated. A report on the original test appears in A.S.M.E. *Transactions*, October 1954. Based on information obtained on this new material in the current Rensselaer tests, we are most optimistic of the results.

The plans reported by Messrs. Fox and Conrad for making hot ductility tests on piping materials appear to be a step in the right direction. However, the data given in our paper must be confirmed by more conclusive relations between hot ductility and service performance before an acceptable standard for rejections can be determined.

Mr. Blumberg's personal contributions have been an important factor in the success of the project. Mr. Blumberg suggests that the hot shortness found in certain specimens may be due to the coarse grains in the heat affected zone, in which the majority of the cracking has been found. While coarse grain has been blamed for many of the difficulties occurring in the fabrication and welding of austenitic steels, we find no evidence to conclude that coarse grain alone is responsible. It is likely that some weakness occasioned by the welding or the chemistry of the base metal, not yet identified as such, may be the factor which promotes the hot shortness observed.

We are in agreement with Messrs. Curran and Rankin that the lower yield strength of 16-8-2 during the weld deposition contributes to the success of welding with this electrode by, as we said, its capacity to "absorb the stresses resulting from welding without imposing more stress upon the adjacent parent metal in the hot adjacent zone than it was able to take, particularly if the material were hot short . . ." We await with interest the tests which these gentlemen intend to make to determine the basic factors which define the hot ductility of the austenitic steels.

HENRY M. SOLDAN
Public Service Gas
and Electric Co.
CHARLES R. MAYNE
International Nickel Co.



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Personal Mention

Cyril Stanley Smith

CYRIL STANLEY SMITH, professor of metallurgy and former director of the Institute for the Study of Metals at the University of Chicago, has been elected to the National Academy of Sciences.

Dr. Smith, who has headed the Institute since it was formed in 1945, resigned his administrative duties last month to devote full time to basic research in the physical structure of metal alloys.

A Britisher by birth, he came to the United States in 1926 to study at Massachusetts Institute of Technology. After receiving his doctorate degree, he joined the American Brass Co., Waterbury, Conn., serving 15 years as research metallurgist.

Well-known for his work on the Manhattan District project at Los Alamos during the war, Dr. Smith was associate division leader of the chemistry and metallurgy division there, and directed the group which determined the basic factors in the metallurgy of uranium-235 and plutonium. The U.S. Medal of Merit was awarded him for his work during these years. After the war, he came to the University of Chicago to direct the Institute for the Study of Metals.

Dr. Smith recently was on a year's leave of absence conducting research on the history of science, under the support of the Guggenheim Foundation and the National Science Foundation. He also attended the International Conference on Peaceful Uses of Atomic Energy at Geneva last year as an advisory member of the U.S. delegation.

William H. Wills, Jr., has changed his position from product metallurgist, tool steels, for Universal-Cyclops Steel Corp., Titusville, Pa., to service metallurgist, Allegheny Ludlum Steel Corp., Dunkirk, N.Y.

Jacob P. Frankel, formerly associate professor of metallurgy at Northwestern University, is now a member of the professional staff of Systems Laboratories Corp., Sherman Oaks, Calif., working on nuclear propulsion for space ships.

James Dobbin has left the U.S. Air Force and joined the Aluminum Co. of America as a metallurgist at the Davenport, Iowa, sheet and plate mill.

George A. Ball, Jr., has accepted the post of geophysical engineer for the Magnolia Petroleum Co., an affiliate of Socony-Mobil Inc. He will be working out of a field office in Sanderson, Tex.

William N. McArdle has resigned from Rotary Electric Steel Co., Detroit. Formerly Chicago district sales manager, he joined the company at the outset of their stainless steel program.

James O. Light was advanced from superintendent, openhearth and foundry department, to division superintendent, Lower Works operations for the Lorain, Ohio, works of the National Tube Div., U.S. Steel Corp. Mr. Light, who came to the Lorain works in 1936 after graduation from Pennsylvania State College, will have responsibility for the direction of the coke plant, dock and slag crusher, blast furnaces, openhearth and foundry, bessemer and rolling mill.

Gary Steven, until recently senior metallurgist in the metals research department, Armour Research Foundation of the Illinois Institute of Technology, Chicago, has become a member of the staff of Crucible Steel Co. of America's research laboratory in Pittsburgh. Mr. Steven will be active in tool and die steel research as well as in the development of constructional alloy steels.

Paul P. Ventura has been promoted to vice-president and director of Eastern Heat Treating & Brazing Corp. and its affiliate, Eastern Metals Industries, Inc., New York. Associated with Eastern since 1956 as general manager, Mr. Ventura was chief engineer and research and development engineer at Croll-Reynolds Engineering Co., New York, prior to that.

Bernard J. Alperin has been named development engineer for the applied research and development laboratory of the General Electric Co. foundry department, Schenectady, N.Y. After graduation from Massachusetts Institute of Technology in 1952, Mr. Alperin joined General Electric as a nonferrous metallurgist at the Erie foundries and retained this position until his present appointment.

James L. Baker has resigned his position as chief metallurgist with the Seymour Mfg. Co., Seymour, Conn., to accept a post in the research and development department of Chase Brass & Copper Co., Waterville, Conn.

Alan G. Caterson is now supervisor of commercial applications and sales promotion for Rem-Cru Titanium, Inc., Midland, Pa. In this capacity, Mr. Caterson will direct the company's market development and commercial sales programs, as well as public relations and advertising. After four years as a research engineer for Westinghouse Electric Corp. in Bloomfield, N.J., he joined Rem-Cru's metallurgical research staff in 1953 and later transferred to the sales department to edit technical literature.

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only* PAINT-GRIPPING, CORROSION-RESISTING TURCOAT 4178 *offers you all these plus values!

QUICK FIXING—Turcoat 4178 coatings become non-smearing immediately upon withdrawal from processing. Parts can be handled freely *while still wet* without danger of smearing or streaking coating.

MEETS MIL-C-5541—Used by aluminum fabricators the nation over for government and non-government jobs involving aviation, building parts, household appliances, luggage, ornamental aluminum, aluminum foil, irrigation pipe, automotive and truck parts and bodies, etc.

EASY TO USE—Applied by spray, dip or hand methods. Requires no heating... no electric current. Easily controlled by mere pH adjustment.

UNIFORM—No light tell-tale untreated sections around welds, corners or holes.

ECONOMICAL—Used at low concentrations. Extremely long-lived. Will accept tremendous contamination without loss in efficiency.

COLORS—Available in gold iridescent or natural aluminum.

FREE **SHOWING—TRAINING MOVIE!**
"ALUMINUM FINISHING"

New full-color film visually demonstrates every aspect of aluminum finishing from laboratory theory to authentic production-line techniques filmed on-the-spot during mass production. If your plant or technical group is interested, write today for full details without cost or obligation.

WRITE FOR TECHNICAL DATA... FREE! 4 pages full of technical information on Turcoat 4178, the quick-fixing aluminum conversion coating. Write for your *free* copy, without obligation... *today!*

TURCO PRODUCTS, INC.
Chemical Processing Compounds
6135 SO. CENTRAL AVE., LOS ANGELES 1, CALIF.
Factories: Newark, Chicago, Houston, Los Angeles, London, Rotterdam, Sydney, Mexico City, Naha (Okinawa)
Manufactured in Canada by B. W. Deane & Co., Montreal
Offices in all Principal Cities

MAIL COUPON TODAY!
TURCO PRODUCTS, INC.
6135 So. Central Ave., Los Angeles 1, Calif.
- ☐ Please send free technical information on Turcoat 4178
- ☐ Please send details on the training film "Aluminum Finishing."
- ☐ Please have salesman call

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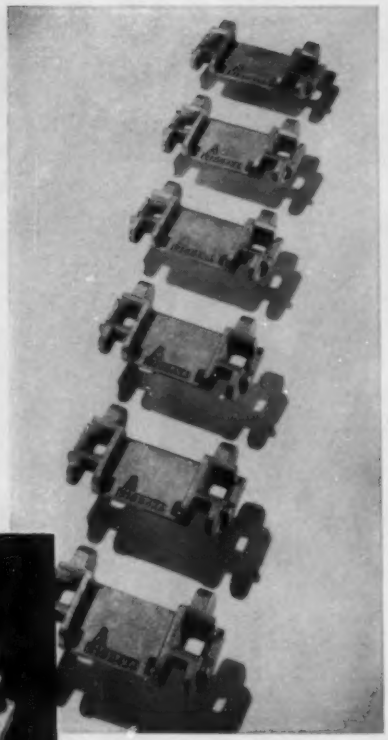
QUARTER MILLION

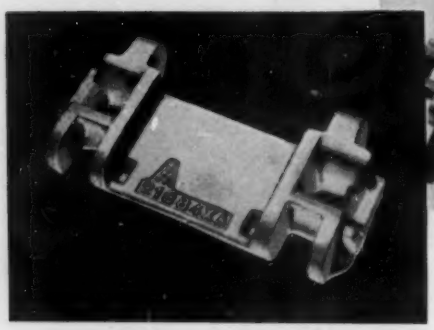
"STEPS"

IN THE

RIGHT

DIRECTION . .





Today's Modern Miner does BETTER with UNITCASTINGS!

Real proof of the continuous high quality of Unitcastings is the fact that more than 99 percent of the total production of 250,000 treads has been accepted!

Continual operation in underground grit and dust subjects mining machinery treads to extreme abuse. Replacement is difficult and expensive, particularly on this section of the equipment, and parts must be made to last!

For over a decade, the abrasion-resistance quality of Unitcast's T-Loy 34 has answered this tread problem—as well as many other special parts for the same equipment.

Take a step in the right direction, too—*you'll do better with Unitcastings!* They're Engineered!

UNITCAST CORPORATION • Toledo 9, Ohio

In Canada: CANADIAN-UNITCAST STEEL, LTD., Sherbrooke, Quebec

Unitcast

SPECIFICATION STEEL CASTINGS

Personals . . .

K. R. Piekarski is president of the newly formed Japan Industrial Equipment Co. of Canada Ltd., Toronto. The company will design custom equipment in Canada for manufacture in Japan. A native of Poland, Mr. Piekarski came to Canada in 1951 to head the metallurgy department of the Ryerson Institute of Technology, Toronto. Before his recent appointment he was engineering manager for MN Automation Ltd., a firm of automation consultants.

W. Paul Eddy, chief of engineering operations at the Pratt & Whitney Aircraft Div., United Aircraft Corp., has been elected president of the Society of Automotive Engineers for 1957. Active in S.A.E. for 20 years, he was vice-president in 1955 and is a former chairman of the Southern New England Section. Mr. Eddy has been with Pratt & Whitney for thirteen years and has held his present post since 1946.

John D. Fowler has been added to the sales staff of Pennsalt Chemicals, Philadelphia, and will work out of the company's Hamilton, Ont., office. Mr. Fowler was technical service engineer with Consolidated Mining & Smelting Co. of Canada, Ltd., before joining Pennsalt.

Lewis E. Thelin, formerly assistant chief metallurgist, has been named manager of technical service of the Bristol Brass Corp., Bristol, Conn.

Charles H. Schwerin has resigned as manager, industrial furnace division of the Gas Machinery Co., Cleveland. However, he will continue to serve the company as a consultant.

John S. Billingsley has been named to the newly created position of assistant to the vice-president, sales, for Crucible Steel Co. of America, Pittsburgh. After serving in various sales capacities for 34 years, he was made central area sales manager in 1954 and held that job until his recent promotion.

Malcolm F. Judkins, manager of the new products division, sales department, Firth Sterling Inc., Pittsburgh, has become director of new product development.

OHIO SEAMLESS TUBING

SPEEDS UP DRILLING 25%

Pennsylvania Drilling Company, Pittsburgh, manufactures drilling equipment for foundation testing, mineral prospecting and other drilling, boring and sampling operations. Recently they introduced a new Flush-Joint Drive Casing made from cold drawn OSTUCO Seamless Steel Tubing.

The new casing stepped up overall drilling progress 25%—driving and pulling is easier and quicker. Flush-Joint Casings are stronger, too—actually 50% less breakage . . . with resultant savings in downtime, repair and material costs. Success with the new casing led to its incorporation in Penndrill's newly-designed Testborer which augers, automatically samples and drives and core drills.

There's a good chance OSTUCO Tubing components can improve the performance of your product. You can start the process by contacting the nearest Ohio Seamless sales office, or by writing direct to the Shelby factory.

OSTUCO SHELBY, OHIO

OSTUCO TUBING

MANUFACTURED IN

SHELBY, OHIO

EXCLUSIVELY BY

OHIO SEAMLESS TUBE DIVISION

OF COPPERWELD STEEL COMPANY

SHELBY, OHIO • Birthplace of the Seamless Steel Tube Industry in America

SEAMLESS AND ELECTRIC-RESISTANCE WELDED STEEL TUBING • FABRICATING • FORGING

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CANADA: Railway & Power Engr. Corp., Ltd.

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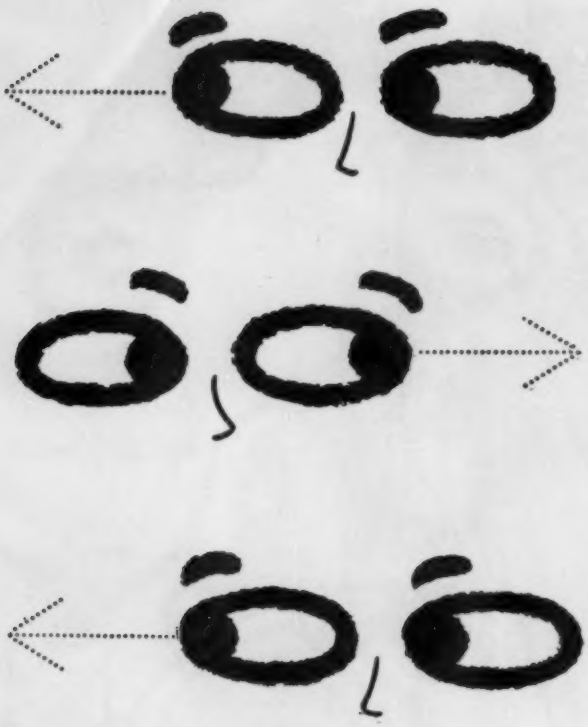


Alternating stresses bear watching!

Back and forth . . . up and down . . . in and out . . . if those stresses keep changing, the life of a metal part is a hard one . . . and often a short one. Stress reversals can cause "fatigue" failure at stresses far below the expected strength of the metal.

One of the outstanding properties of phosphor bronze is its high resistance to fatigue failure. It is widely used for electrical switch parts, relay contact springs, bellows, rotating shafts and other moving or vibrating parts.

For detailed information on phosphor bronze, write to Riverside-Alloy Metal Division, H. K. Porter Company, Inc., Riverside, N. J.

ALLOY METAL WIRE
Prospect Park, Pa.

RIVERSIDE METAL
Riverside, N.J.

PRENTISS WIRE MILLS
Holyoke, Mass.

HKP RIVERSIDE-ALLOY METAL DIVISION
H. K. PORTER COMPANY, INC.

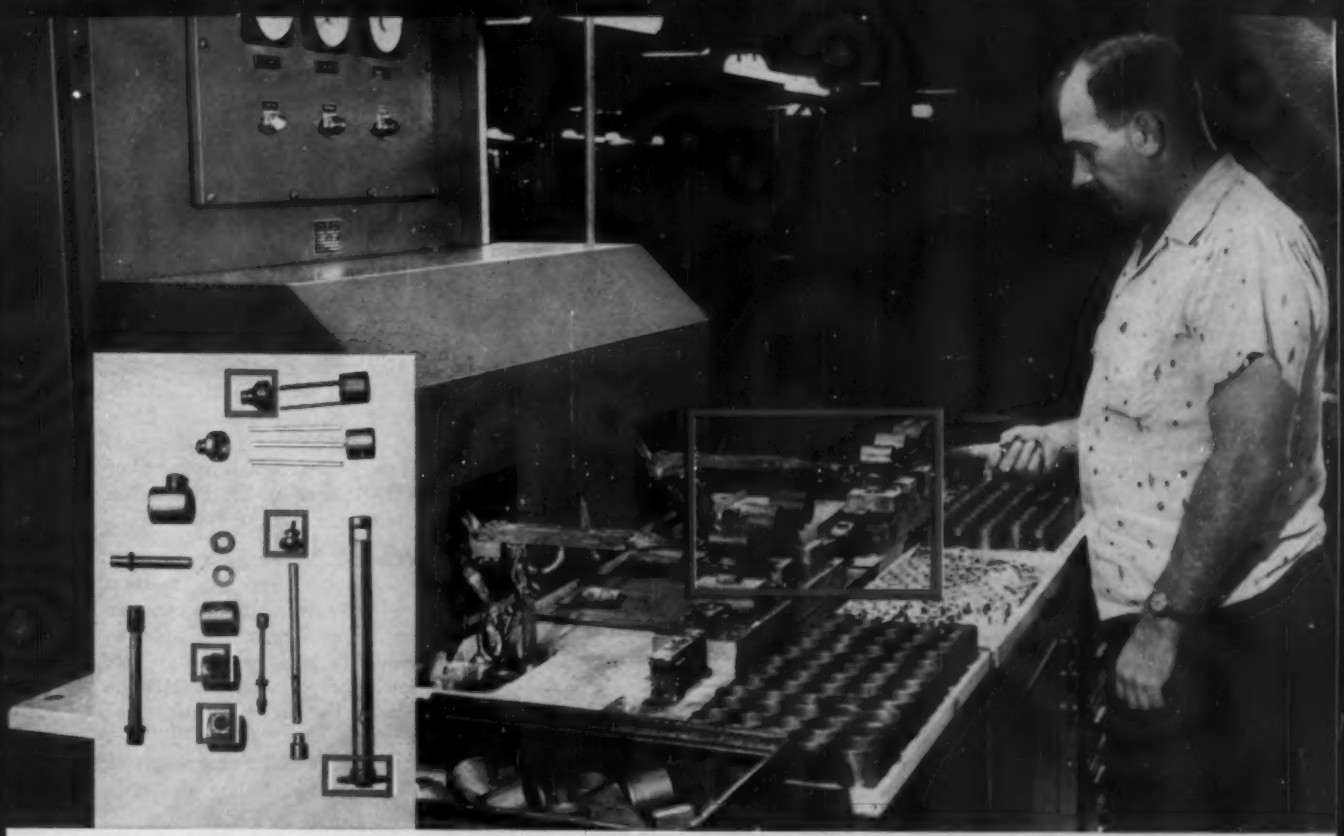
Personals . . .

Kenneth C. Kelly is one of several Crucible Steel Co. of America men named to newly created positions in the company's expanding sales department. Mr. Kelly, who joined Crucible in 1927 as a sales trainee, will serve as southern regional sales manager with headquarters in St. Louis. Since 1949 he has been branch manager of the St. Louis office. The former manager of the company's Boston sales branch, **Henry A. Sturm, Jr.**, will fill the new position of New England regional sales manager. Serving in various company sales positions since 1937, Mr. Sturm was transferred to Boston in 1951 as assistant manager and later became manager of that office. Two new positions in the Pittsburgh home office will be filled by **G. Whitney Snyder** and **Robert M. Simpson**. Mr. Snyder, named assistant general sales manager, product divisions, joined the executive sales staff in 1954 after seven years in other Crucible departments. Mr. Simpson will develop and direct over-all field sales programs as assistant general sales manager, field sales. Since joining Crucible in 1940, he has served in the Park Works in Pittsburgh and on the west coast as San Francisco manager and Los Angeles branch manager.

R. C. Lindsay has been transferred to White Sands Proving Grounds, N.M., from his position as manager, administration, for the Radio Corp. of America Airborne Systems Laboratory, Waltham, Mass. In his new position, Mr. Lindsay is administrator for R.C.A. Missile Technical Operation, a test installation for an RCA missile guidance system, and is responsible for all financial and facilities services.

Earl D. Levine was released from the Army last fall and returned to Rensselaer Polytechinic Institute to study for a master's degree. While in the service, he was stationed at Frankford Arsenal, and did metallurgical research at the Pitman-Dunn Laboratories.

R. A. Canning is now manager of manufacturing in the newly formed magnetic materials section of General Electric Co. metallurgical products department, Detroit.



AT HARTFORD MACHINE SCREW CO.—

General Electric induction heaters braze 20 different parts, help cut rejects 91%

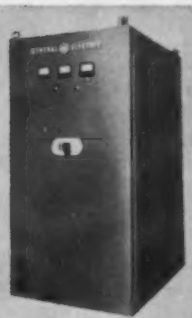
At Hartford Machine Screw Co., a General Electric electronic induction heater is used for brazing a wide variety of parts for electric-switch housings and jet engines.

The General Electric unit takes on jobs ranging from ¼-inch to 1½-inch tubing. After brazing, each part undergoes a regular 500-pound pressure test, and the aircraft work must pass radiographic inspection. With the General Electric induction heater, rejects have been reduced 91 per cent, from 30-35 per cent to a maximum of two per cent.

"If we need another induction heater, it definitely will be a General Electric," says A. O. Haversat, plant engineer. "The output control alone makes it virtually a MUST. This feature is just what we need for our kind of production. It eliminates guesswork and costly human errors. And it cuts out excess tooling, while still assuring uniform brazing."

General Electric electronic induction heaters are available in four ratings—7½-15-, 25-, and 40-kw, with a choice of four different models in each rating. The four models provide various control combinations, so you can buy the one induction heater which best matches your production pattern from the standpoint of both rating and control.

For more information, send in the coupon below or contact your nearby General Electric Apparatus Sales Office.



Four models in each of four ratings; 7½ Kw, 15 Kw, 25 Kw, and 40 Kw.

General Electric Co.
Section 722-6
Schenectady, N. Y.

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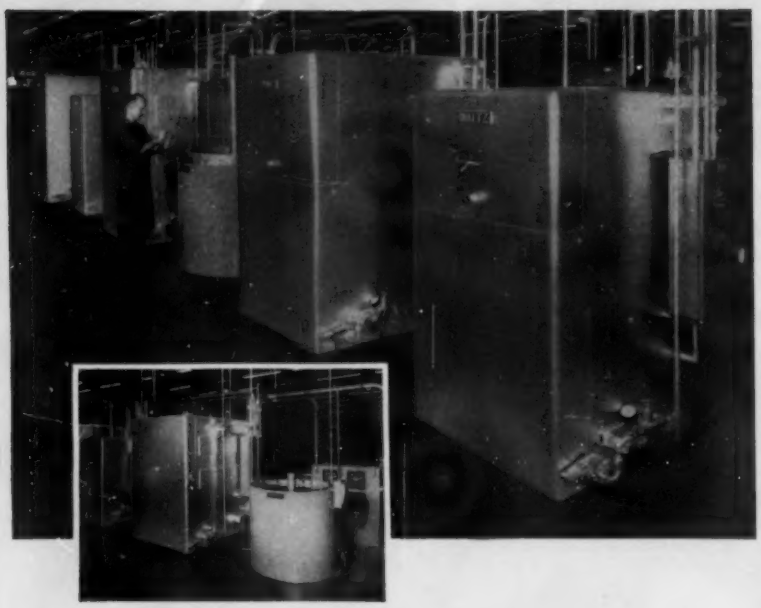

Waltz furnaces have

the forward look

at Chrysler Corporation

When equipping Chrysler Corporation's new TorqueFlite automatic transmission plant at Kokomo, Indiana, Chrysler engineers demanded equipment capable of top performance. WALTZ Furnaces were selected for the automotive tool room.

In addition to delivering the performance required, Waltz Furnaces also are attractive, smooth, easy-to-clean. Outer shells reach all the way to the floor to prevent unsightly and dangerous clutter usually found under ordinary furnaces. Waltz doors fit flush and tight, are opened with a convenient foot pedal control. Cabinet-type control panels are neatly wired to terminal blocks for easy installation.

Performance-appeal? Waltz has plenty. Just try to match the amazing versatility of a Waltz furnace. Originally installed by Chrysler just to handle the needs of the automotive tool room, the furnaces shown in the illustration were soon called on to handle many pilot parts, as well as regular production runs. Chrysler stayed right on schedule. So can you!

A complete line of Waltz standard or special heat-treating furnaces, using all types of fuels, is built to suit your requirements. Write for comprehensive illustrated bulletins to Dept. W.

Choice Distributor Territories Now Open

Waltz FURNACE COMPANY

SYMMES STREET • CINCINNATI, OHIO

Personals . . .

Tien-Shih Liu has taken a position as senior research metallurgist at Titanium Metals Corp. of America, Henderson, Nev. Dr. Liu was a project supervisor at Horizons, Inc., Cleveland, before accepting his new post.

John E. Anderson has left General Electric Co.'s Evendale, Ohio, plant, where he was a metallurgical engineer, to accept the post of project engineer for the Parker Pen Co., Janesville, Wis.

William F. Carew, for the past five years in charge of the creep testing laboratory at the Armour Research Foundation of Illinois Institute of Technology, Chicago, has accepted the position of chief engineer with the Joliet Metallurgical Laboratories, Inc., Joliet, Ill. His work will involve the supervision of various phases of testing of metals at elevated temperatures.

William A. Mossner left the Ladish Co., Milwaukee, Wis., in October to go on active duty with the U.S. Air Force. At the present time, he is an interceptor controller at the Rockville, Ind., Air Force Station and prior to this assignment was training in Florida.

Robert P. Marks is the Pacific Northwestern representative for Allen Mfg. Co., Hartford, Conn. Mr. Marks has also worked in the capacity of sales engineer for the E. W. Bliss Co. plant in San Jose, Calif., and Pacific Foundry Co., San Francisco.

John P. Jones, a recent graduate from West Virginia University, has joined Rem-Cru Titanium, Inc., Midland, Pa., as a research mechanical engineer.

Wilbur Kattner has left the Hanford Atomic Products Operation of General Electric Co., Richland, Wash., to join Consolidated Vultee Aircraft Co., Fort Worth, Tex., as a project nuclear engineer. During 12 years at Hanford, Mr. Kattner worked in engineering, and research and development in fuel element technology; his present job at Convair is research covering radiation effects upon materials of interest in nuclear propelled aircraft.

"Our equipment has to produce — so we got PANGBORN BLASTMASTERS"

says Mr. W. BLACKMER, Foundry Superintendent,
Muskegon Piston Ring Company, Sparta, Michigan

4 Blastmaster® Barrels replace 6 air blast barrels and 10 tumbling mills . . . cut two and three shifts a day to just one

"We maintain over 4,000,000 finished castings in stock for immediate shipment. To keep this stock replenished, our blast cleaning equipment has to really turn out the work. And we want a good job, too! We have found that our Pangborn Blastmasters fill the bill on both points—production per manhour is amazing."

If *you* need blast cleaning equipment, look at all makes. Then check the Pangborn Blastmaster. You'll find it offers many exclusive features plus a choice of sizes to fit your needs—1½, 3, 6, 12, 18 and 27 cu. ft. Write for Bulletin 703 to PANGBORN CORP., 1800 Pangborn Blvd., Hagerstown, Maryland. *Manufacturers of Blast Cleaning and Dust Control Equipment.*

Pangborn blast cleans cheaper

careers in the peaceful applications of atomic energy

Join a leader in research, development, design and manufacture of nuclear reactors for industry, power, medicine and scientific study.

METALLURGISTS

B.S., M.S., or PhD.—with training or experience in physical metallurgy of nuclear fuel materials; in metallography of both fuel and construction materials; in high temperature material (both alloy and ceramet) development and evaluation; in vacuum melting and casting techniques; or in mechanical fabrication related to fuel element manufacture.

MECHANICAL ENGINEERS

For development work in the Pyroprocessing Refabrication Experiment. To develop equipment for remote high temperature decontamination and remote refabrication of nuclear fuels.

Write: Answer will be prompt and confidential

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

Mr. G. W. Newton, Personnel Office, Dept. MP-6
21600 Vanowen Street, Canoga Park, California
(In the Suburban San Fernando Valley, Los Angeles)

Personals . . .

Frank E. Binns, recently discharged from the U.S. Air Force with the rank of captain, is now employed as project manager in charge of advanced development and design for the manufacturing department of the nuclear division of the Glenn L. Martin Co., Baltimore, Md. Mr. Binns' responsibilities will include management of some small nuclear projects which have passed the advanced engineering stage.

James F. Buck, a March 1956 graduate of the South Dakota School of Mines & Technology, is now employed at E. I. du Pont de Nemours & Co., Inc., Sabine River works in Orange, Tex.

John Price Hirth, a metallurgical engineering student at Carnegie Institute of Technology, has been awarded a Fulbright Scholarship to study metallurgy at the University of Bristol in England.

Carl J. Oxford, Jr., has been advanced to the position of director of research for National Twist Drill & Tool Co., Rochester, Mich. Formerly research engineer for the company, Mr. Oxford will now be in charge of all laboratory and research activities with special emphasis on the various aspects and problems connected with metal cutting.

Bernard S. Lement has become director of research, division of physical metallurgy, Manufacturing Laboratories, Inc., and is engaged in an investigation of titanium alloys sponsored by Wright Air Development Center. Dr. Lement has been connected with Watertown Arsenal, University of Notre Dame and Massachusetts Institute of Technology.

David L. Wheeler, formerly affiliated with Alco Products Co., Schenectady, N.Y., is now a research engineer at the research laboratory of Armco Steel Co., Baltimore, Md.

Gene E. Bobeck, after receiving his master of science degree in metallurgy from Iowa State College in December, accepted a position as metallurgist on the technical staff of the Dow Chemical Co. Rocky Flats plant in Denver.

200 Different Parts Heated for Forging-

Better, Faster and at Much Lower Cost

with TOCCO* *Induction Heating*

• When progressive production people at General Railway Signal Company installed a 200 kw, 3000 cycle TOCCO machine, they were able to eliminate 7 slot-type oil-fired furnaces and produce better forgings than ever before—at substantially lower costs.

Cost Down—Fuel costs have been reduced from $15.26 to $1.60 per hour with TOCCO. Expensive furnace lining maintenance has been eliminated, and straightening and reheating operations formerly required are no longer necessary.

With oil-fired furnaces all steam hammer operators needed helpers. With TOCCO most of these helper operations have been eliminated.

TOCCO's fast, automatic operation produces almost no scale and achieves uniform temperatures throughout the entire cross section—improving the quality of the forgings and providing increases of up to 40% in the life of the forging dies.

Overall production costs in the forge shop at G.R.S. have been reduced an impressive 35%!

Flexibility—Production runs at G.R.S. range from a low of 15 pieces to a high of over 50,000. Parts from ½ pound to over 25 pounds are heated, merely by changing inductor coils and power control settings.

Better Working Conditions—TOCCO makes the forge shop a better place to work by doing away with noise, dust, dirt, smoke and radiant heat and gases produced by old fashioned furnaces.

If you're looking for a way to produce similar results in your plant, it will pay you to consult a TOCCO Engineer.

TOCCO

JUST PUSH A BUTTON

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Please send copy of "Typical Results of TOCCO Induction Heating for Forming and Forging".

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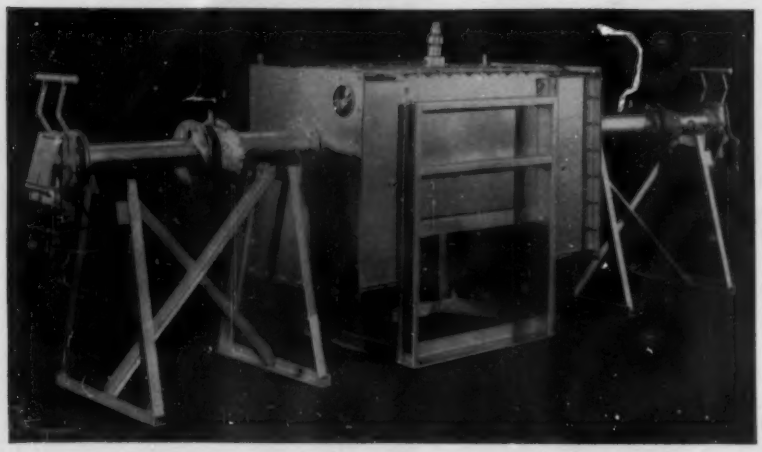
Another Harper First:



A COMPLETE LINE OF FURNACES FOR 5000° F.

NOW, FOR THE FIRST TIME, the complete line of Harper Graphite Tube Furnaces offers you a choice of 1" to 6" tube diameters for your high temperature research and special production work.

These furnaces will give you uniform, controlled-atmosphere heating of work within a tubular graphite resistance element, provided that no fumes or gases harmful to graphite are present. They are designed to maintain temperatures up to 5000° F. within the element, which is mounted in an adequately insulated, gas-tight metal chamber. You must use either reducing or neutral atmospheres.

Each of the seventeen standard models includes an entrance chamber, a heating chamber, and a water-cooled chamber for atmosphere cooling. Doors are provided at both ends, and for dry atmosphere applications, purge chambers can be included.

You may push the material through the furnace manually or let an automatic mechanical pusher do it for you.

Auxiliary equipment normally consists of a transformer control unit and temperature indicating and controlling instrumentation which is operated through radiation type temperature detectors.

Interested in more information? Please write for Bulletin CT-1156. Harper Electric Furnace Corporation, 52 River Street, Buffalo 2, New York.

Many other Harper research furnaces available to match your temperature, size and atmosphere requirements.

HARPER
ELECTRIC FURNACE CORP.
40 RIVER STREET • BUFFALO 2, N. Y.

Personals . . .

Walter Holcroft, executive vice-president of the Holcroft Co., Detroit, was elected president of the Industrial Heating Equipment Assoc. as its annual meeting early this year. **Carl Ipsen** was re-elected executive vice-president and **C. Floyd Olmstead,** president of Lee Wilson Engineering Co., Cleveland, was named vice-president.

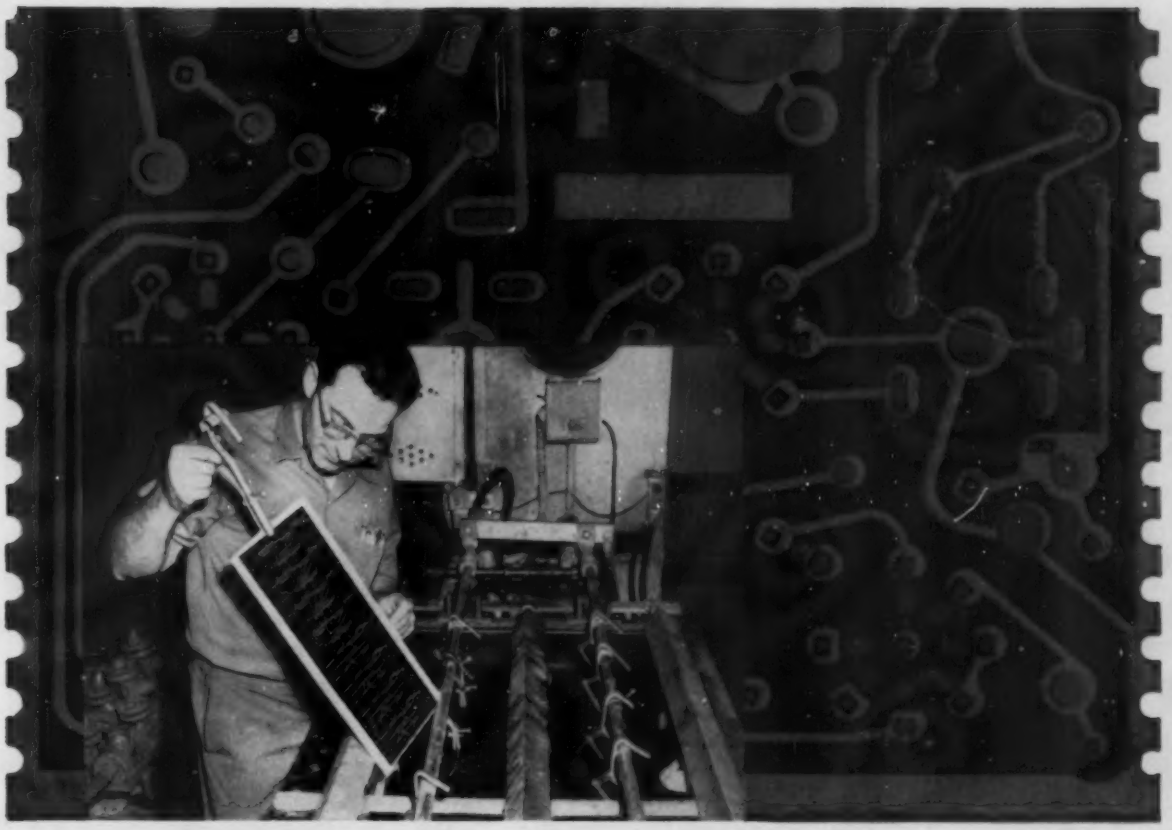
J. Robert Douslin and **Leo W. Ollila** have both received promotions in the Wyman Gordon Co., Worcester, Mass. Mr. Douslin, works manager of the North Grafton, Mass., plant since 1956, will now serve as district sales manager in Los Angeles. Affiliated with Wyman Gordon since 1942, Mr. Ollila will change positions from metallurgical manager to works manager of the Worcester plant.

Clee O. Worden recently joined the Edgcomb Steel Co. as manager, toolsteel sales, Philadelphia. Previously he had been a sales representative in the Philadelphia area for Northeastern Steel Corp., Bridgeport, Conn.

Marcel A. Cordovi, head of the materials and testing department of the Babcock & Wilcox Co., New York, atomic energy division, rereived the second annual Industrial Achievement Award of the New York Chapter for his "brilliant achievements in the field of metallurgy". In addition to his duties at Babcock & Wilcox, Mr. Cordovi is an adjunct professor of metallurgical engineering of the Polytechnic Institute of Brooklyn, a metallurgical consultant to Brookhaven National Laboratory and the official United States representative to the International Institute of Welding.

Donald M. Werner has assumed the post of sales manager of the special products division of United Steel Fabricators, Inc., Wooster, Ohio. He will be in charge of sales of the company's custom fabricated products.

Richard R. Flowers, a research metallurgist in the manufacturing research laboratory of American Steel Foundries, is now associated with the U.S. Bureau of Mines, Tucson, Ariz.



HOW TO PLATE PRINTED CIRCUITS

FASTER, BETTER, AT LOWER COST

...with B&A Fluoborates

First step—use B&A copper fluoborate for high-speed copper plating of thick, high quality circuits.

Second step—use B&A lead-tin fluoborate for maximum solderability (60:40 tin-lead deposit).

Advantages: Both of these high purity fluoborate plating solutions come in concentrated solution form. They give you easy bath make-up and easy control. Since anode and cathode efficiencies approximate 100%, you get easy maintenance, too. They require no mixing or dissolving, and offer excellent bath stability, good anode corrosion.

Result: You produce *better* printed circuits, *faster* and *at lower cost—more easily*, too!

Mail coupon now for comprehensive technical bulletins giving complete information on these improved plating techniques for printed circuits.

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Please send technical bulletins on the use of B&A Fluoborates in the production of printed circuits.

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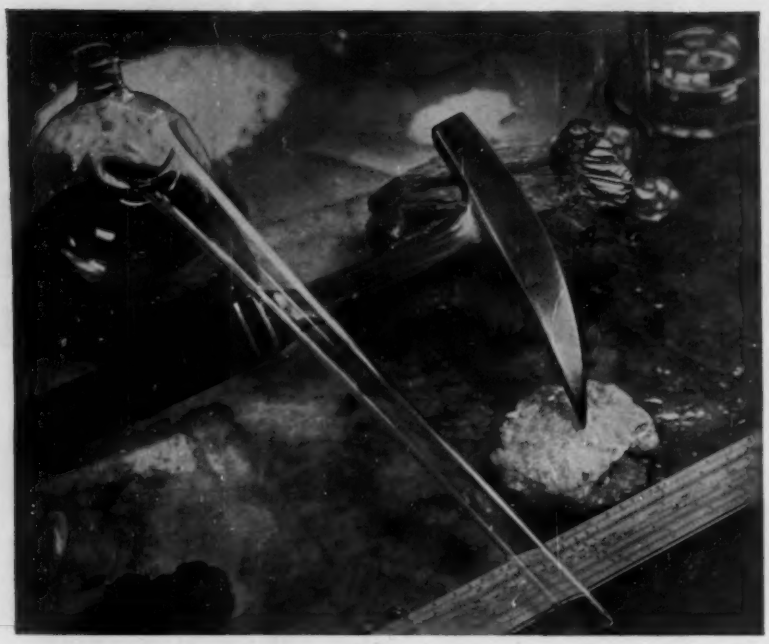

THE HAMMER
AND THE RETORT

As the geologist's hammer signifies the mineral wealth locked in the earth's crust, the chemical retort signifies the power to free that wealth for the benefit of mankind. Together, the hammer and the retort symbolize the marriage of geology and chemistry that is the tradition and the future of the Foote Mineral Company.

Founded eighty years ago as a supplier of mineral products, Foote has expanded constantly, until now its business includes mining, mineral and alloy processing, chemicals, and metals. And the pioneering done by the company in the extraction and application of many lesser known elements has contributed substantially to many important technological advances.

Foote Mineral Co., 424 Eighteen West Chelten Building, Philadelphia 44, Pennsylvania.

Foote
MINERAL COMPANY

RESEARCH LABORATORIES: *Berwyn, Pennsylvania*
PLANTS: *Cold River, N.H.; Exton, Pa.; Kings Mountain, N.C.; Knoxville, Tenn.; Sunbright, Va.*

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Personals . . .

Grant A. Morrison, formerly Carboloy cemented component parts representative in the Houston, Tex., area for the metallurgical products department of General Electric Co., has transferred to Detroit as engineering administrator in the organization's engineering section. Mr. Morrison became affiliated with General Electric in 1951, handling several marketing assignments in the southwest prior to making his headquarters in Houston.

A. R. Schneller has been appointed sales manager of welding products and accessories for the welding products division of the A. O. Smith Corp., Milwaukee, Wis. Mr. Schneller's previous position was eastern regional sales manager for welding products.

William F. Ross has accepted the post of marketing manager of Ipsen Industries, Inc., Rockford, Ill., Ipsenlab of Rockford, Inc., and Ipsenlab of Canada, Ltd. Before coming to the company, he was manager of the industrial furnace division of A. F. Holden Co., Detroit, and prior to that was a partner in the firm of J. E. Von Maur Co., Columbus, Ohio.

W. William Nash has resigned as plant metallurgist at the Burroughs Research Center, Paoli and Great Valley, Pa., to accept the position of metallurgist with Rohr Aircraft Corp., Chula Vista, Calif. He previously was employed as metallurgist for Vertol Aircraft Corp. and Sikorsky Aircraft Div. of United Aircraft Corp.

Gerald H. Waite, a recent graduate of the University of Nevada with a bachelor's degree in metallurgical engineering, is now employed as a process analyst at Consolidated Vultee Aircraft Corp., Pomona, Calif.

Jacob D. Gubbay has joined the research and development group at LaSalle Steel Co., Hammond, Ind., as metallurgical research engineer and has taken the company's three-month training program. Previously, he worked in the heat transfer research laboratory of Massachusetts Institute of Technology.

Shown is a Drever Gas-Fired Strip Belt Conveyor Furnace for reducing and drying copper powder at the rate of 10 tons per 24 hours at 1000°F.

In the foreground is a Drever Inert Gas Generator for supplying the necessary gases to purge the furnace entry and exit areas.

CONTINUOUS REDUCTION AND DRYING FURNACES

for metal powders

In the manufacture of metal powders, an essential step is the ability of a furnace to completely reduce and dry metal powders and obtain powder of uniform particle density. Experience proves Drever Strip Belt Conveyor Furnaces meet these rigid specifications.

Completely integrated sheet belt furnaces are available for treating oxides of nickel, iron, copper and tungsten. Powder is received from a hopper, leveled on belt and conveyed through a highly reducing atmosphere in the heating and cooling chambers.

Specially designed roll seals keep furnace openings tight while the areas are purged with inert gas. Complete temperature control as well as product uniformity is inherent in the design of these furnaces. They are available for fuel firing, radiant tube or electric heating.

DREVER COMPANY

RED LION ROAD and PHILMONT AVE.
BETHAYRES, PA.

35

ROLOCK

FABRICATED ALLOYS

HEAT AND CORROSION RESISTANT

Make sense and make dollars for pit-type furnace users

ROLOCK'S unique CORRUGATED construction

with pressure-welded truss-type grids

There are many good reasons why these new furnace baskets out-perform and outlast older types. ROLOCK's Corrugated Construction gives high strength with light weight and this, in turn, means less material to bring up to temperature with faster, more uniform heat transfer . . . and a higher ratio of pay load to basket weight. Such baskets mean a substantial saving in furnace time because of faster recovery and, in some cases, an increase in average load as well.

ROLOCK's specialized Welded Fabrication takes full advantage of this construction in every respect. The grid, for example, is built up from rounds rather than flats by a ROLOCK-developed pressure-welding method. Experience shows that such grids are far better able to withstand thermal shock. They may be reversed as required, to compensate for deflection, without cracking.

In this field, as in many other specialized applications of welded-fabricated heat-resistant alloys, ROLOCK's exceptional facilities and skills often promise major operating savings. Write us outlining your problems.

SALES & SERVICE FROM COAST TO COAST

ROLOCK INC., 1222 KINGS HIGHWAY, FAIRFIELD, CONNECTICUT

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

6RLS7

Personals . . .

A. L. Boegehold has retired as manager of research activities and principal assistant to the vice-president in charge of research of General Motors Corp., Detroit. Mr. Boegehold, a veteran of 36 years with General Motors, will continue as a consultant to the research staff of the company. He served as president of the American Society for Metals in 1947 and in 1955 received the Society's Gold Medal. At the same time, **Arthur F. Underwood** was elevated to manager of research staff activities for General Motors. Mr. Underwood had headed the mechanical development department at GM since 1937.

Arthur R. Oakley, Jr., has been appointed sales manager, steel department, of Steel & Machine Tool Sales Co., Houston, Tex. Mr. Oakley is a past chairman of the Texas Chapter (1954-55) and is currently serving on the Metals Handbook Committee. Steel & Machine Tool Sales is the distributor for Crucible Steel Co. of America in the Texas Gulf Coast area.

Charles W. Darby has been appointed to the newly created position of production manager of the spring division, Crucible Steel Co. of America, Pittsburgh. Mr. Darby will be responsible for all production, quality control and maintenance activities for the division. Since joining Crucible in 1940 after graduation from Lehigh University, he has served as metallurgist, supervisor of federal regulations, product service engineer in the alloy and carbon division, and lately as staff metallurgist in the central metallurgical office in Pittsburgh.

H. Daniel Robb has been promoted from the post of manager of alloy steel sales at the St. Louis plant of Joseph T. Ryerson & Son, Inc., to that of national product manager, alloy steels, for the company. His headquarters will be in the company's general offices at its Chicago plant. Mr. Robb came to the Pittsburgh Ryerson plant in 1946, later was transferred to Chisago, and then to St. Louis as plastics department manager. He became a member of the alloy department in 1951 and a year later was named manager.

OX-250 / *a proved G.E. X-Ray product to make your products better*

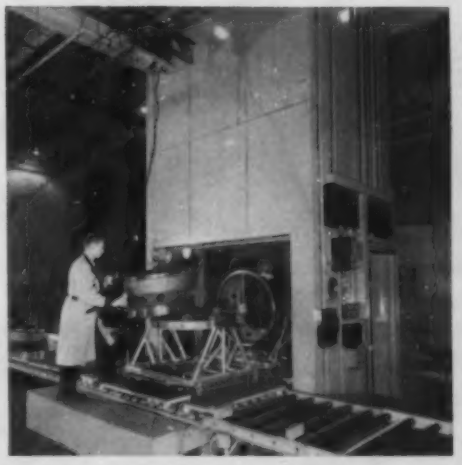
When missions can't fail...

G-E x-ray inspection detects trouble before it starts

This lean and lethal atomic bomber travels lighter, faster, safer thanks to engine weld inspection with the General Electric OX-250. No beefed-up design to compensate for weak welds on its J-57 turbo-jet components. No excess bulk to hamper speed. G-E x-ray spots troubles before they start.

In addition, the semi-automatic OX-250 at Ford's Aircraft Engine Division plant in Chicago does the work of four conventional units. Speeds inspection while it cuts down risks and costs.

Whatever your own production "mission" . . . from light alloy to armor plate . . . General Electric has x-ray apparatus to meet your needs. Call your local representative. Or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin for Pub. AS-64.



FORD AIRCRAFT ENGINEERS GIVE J-57 COMPONENTS A LIFE-SAVING "LOOK" to assure defect-free welds. Stainless steel .093-inch welds on diffuser cases above are about 10 feet long . . . must be 100% sound. Operator prepares second case for radiographing while first case moves into cabinet.

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Violent turbulence:

How to apply it for better quenched parts

Put *turbulence* into the quench bath . . . get better parts out.

That's the experience of men using LIGHTNIN Mixers for violent quench bath agitation. Greater uniformity of hardness all over the part, and from one part to the next. Greater depth of hardness, resulting in higher over-all tensile strength and toughness. No re-treats and rejects due to soft spots. No warpage or cracking. For some steels, better machinability.

Where to get help quickly

You can get LIGHTNIN Mixers for new or existing quench tanks; for use with any quenchant, any type of immersion quenching, pieces of any size, shape, quantity. LIGHTNINS are recommended by leading steel producers.

For complete information on models that will give you the results you want, just call your nearest LIGHTNIN representative (listed in Thomas' Register) or write us today.

WHAT SIZE are your quench tanks? You can get LIGHTNINs to fit them. Illustrated are: (1) *portable*, for clamping to existing tanks (⅛ to 3 HP); (2) *permanent mounting*, for integral construction (¼ to 3 HP); (3) *turbine-type* for large tanks (1 to 500 HP); (4) *side entering* for large tanks, single or multiple installation (1 to 25 HP). Write for descriptive catalogs.

Lightnin® Mixers

MIXCO fluid mixing specialists

MIXING EQUIPMENT Co., Inc., 171-f Mt. Read Blvd., Rochester 11, N.Y.

In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Avenue, Toronto 10, Ont.

Personals . . .

John Cattanach, Jr., has become manager of sales of tubular products and cold finished steel bars at the Buffalo plant of Joseph T. Ryerson & Son, Inc., Chicago. Joining Ryerson in 1933, he was appointed as a field representative in 1941 and remained in that capacity until his promotion to this managerial post.

John F. Black has accepted the post of manager of sales for the newly created steel mill division of Selas Corp., Dresher, Pa. He comes to Selas from Koppers Co., Inc., Pittsburgh, where under his direction, as assistant manager of the Freyn Dept., the first installation for continuous casting of steel slabs was made.

Richard P. Simmons has been named manager of processing for the Toronto, Ohio, plant of the Titanium Metals Corp. of America, a jointly owned subsidiary of Allegheny Ludlum Steel Corp. and the National Lead Co. For the past year, Mr. Simmons has been supervisor of the titanium section of the Allegheny Ludlum Steel Corp. Brackenridge works and before that acted as mill metallurgist in charge of quality and mill development of sheet and strip products.

R. F. Holste has left his job as manager, industrial product planning, with the X-ray department of General Electric Co., to join X-ray Products, Inc., Los Angeles. Affiliated with G.E. for 26 years, in his new position Mr. Holste will hold the title of director of engineering.

George M. Thomas has been appointed project metallurgist in production engineering at the International Business Machines Corp., Owego, N.Y., plant. Joining IBM in 1953, he served successively as technical engineer in the metallurgical laboratory in Poughkeepsie, N.Y., associate metallurgist and staff metallurgist. In 1956, he was assigned to production engineering in the Owego plant.

Richard J. Gennone, a graduate of Lehigh University, is working as senior metallurgist at Reynolds Metals Co. research laboratory, Richmond, Va.

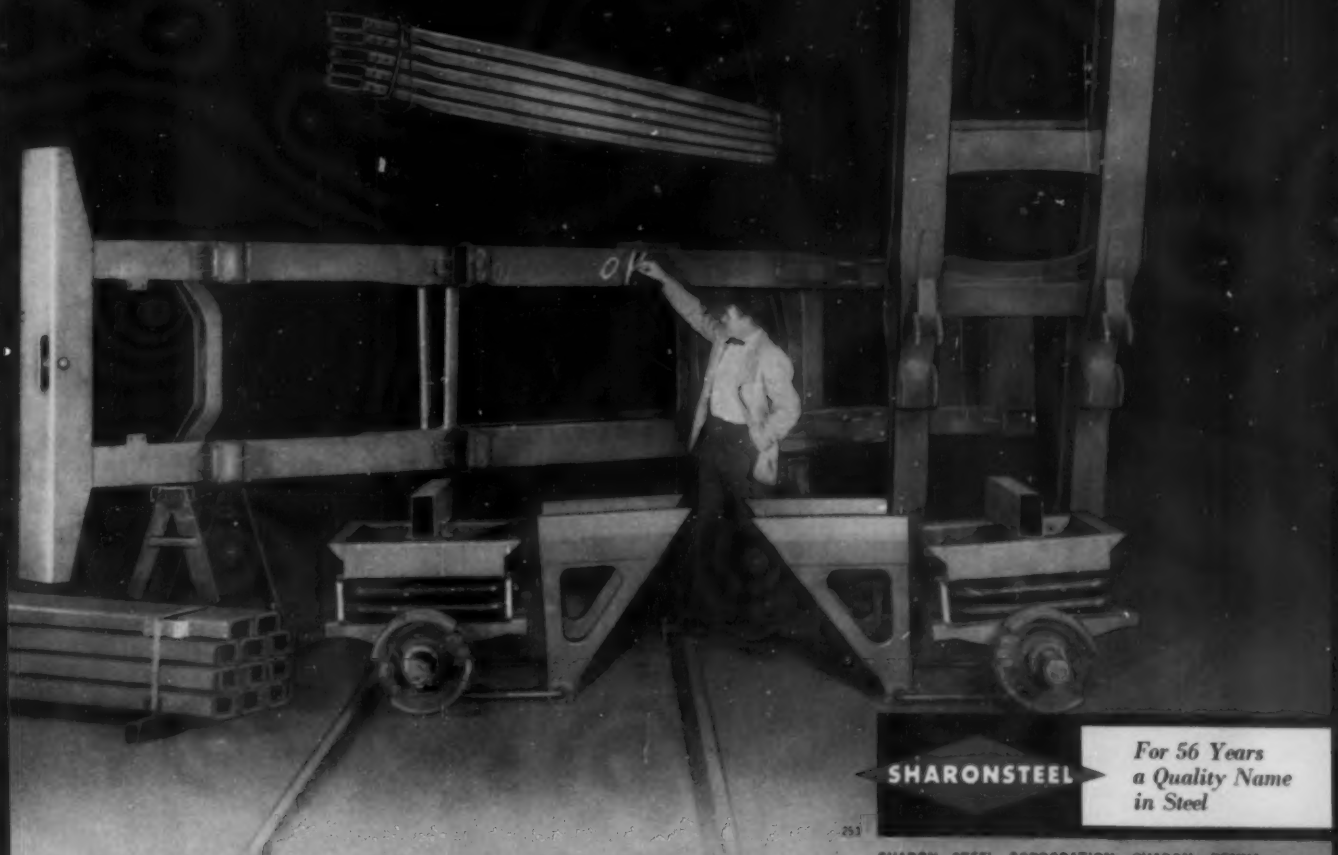
IN TRANSPORTATION EQUIPMENT, TOO

Sharonsteel Quality STANDS OUT

The quality standards and specifications of the transportation equipment manufacturers are known to be among the most exacting in American industry.

For this reason, many leading suppliers of automotive bus, truck and trailer chassies; railway cars; trucks, underframes and the exciting new air spring suspension (foreground) depend on Sharon Steel for high strength, low alloy strip and plate used in their products.

Other types of steel selected by the industry for their high quality are Sharon's line of stainless, coated and alloy strip and plate.



SHARONSTEEL

For 56 Years a Quality Name in Steel

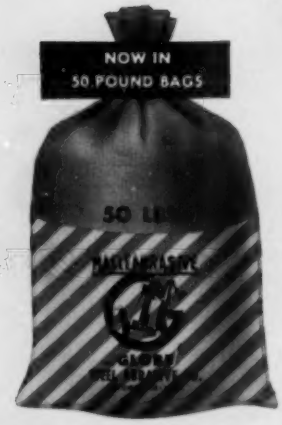
SHARON STEEL CORPORATION, SHARON, PENNA.

CHICAGO, CINCINNATI, CLEVELAND, DAYTON, DETROIT, GRAND RAPIDS, INDIANAPOLIS, LOS ANGELES, MILWAUKEE, NEW YORK, PHILADELPHIA, ROCHESTER, SAN FRANCISCO, SHARON, MONTREAL, TORONTO

what's in a name?

To these proud parents there's only one "Johnny"!

In the field of metal abrasives, there's only one "MALLEABRASIVE", and that's our baby!



"MALLEABRASIVE" is the name of the world's first malleablized abrasive, researched and developed by Globe and famous Battelle Memorial Institute.

No other metal abrasive is the same because only Globe uses the complete process which gives Malleabrasive its own distinctive metallurgical structure.

What's in a name? Just this — the name MALLEABRASIVE represents a standard of excellence that prompts Malleabrasive users to ask, "Is it as good as Malleabrasive?" when urged to buy something similar.

Sold by Pangborn Corporation, and by leading distributors of foundry supplies from coast to coast.

MALLEABRASIVE

THE GLOBE STEEL ABRASIVE CO., MANSFIELD, OHIO ®

1907—Fiftieth Anniversary—1957

Personals . . .

Richard Dale Lambert, a metallurgist in the engineering department of the Duo Therm Div., Motor Wheel Corp., Lansing, Mich., has been promoted to chief inspector of the company's new Delaware plant in Newark, Del.

Raymond C. Bowden, Jr., was recently assigned the post of staff engineer, research and technology department, National Tube Div., U.S. Steel Corp., Pittsburgh. Prior to this appointment, he was assistant manager of the research laboratory of the division.

Adna A. Armstrong, formerly chief metallurgist, special products division of Thompson Products, Inc., Cleveland, has been named manager of the process control laboratory for the valve division of the company.

Reginald Tate recently left Trans Canada Airlines, Montreal, to take a position as materials and processes engineer, Canadian Pacific Airlines, Vancouver, B.C.

James H. Moore has left his position as general manager of vacuum Metals Corp., Syracuse, N.Y., division of Crucible Steel Co. of America, to accept the post of assistant to the president of Metal Hydrides, Inc., Beverly, Mass.

Louis F. Glasier, Jr., has been assigned to the General Electric Co. Vallecitos Atomic Laboratory at Pleasanton, Calif. Prior to that, he was a member of the engineering section of the General Electric Atomic Power Equipment Dept. in San Jose, Calif.

Arthur F. Lockwood has left his position as metallurgist with the Kaiser Aluminum & Chemical Corp., Newark, Ohio, to assume new duties as a metallurgist with Midvale-Heppenstall Co., Philadelphia.

Richard C. Cunningham, manager of stainless sales for Industrial Stainless Steels, Inc., Cambridge, Mass., a wholly owned warehousing and sales subsidiary of Eastern Stainless Steel Corp., Baltimore, has been appointed director of sales for the parent company. Mr. Cunningham has been associated with Industrial Stainless Steels for 18 years and has served in his present position for the past several years.

At Wright Aeronautical Division
Curtiss-Wright Corporation

COMPLEX BRAZING

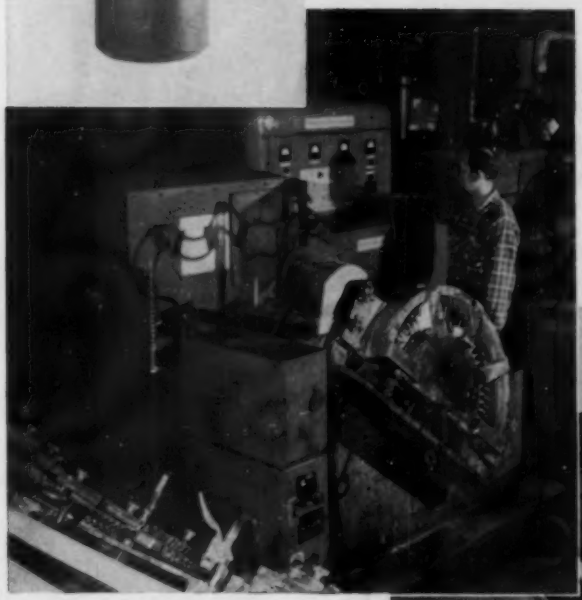
is sure and quick
with R-F Induction Heat
using

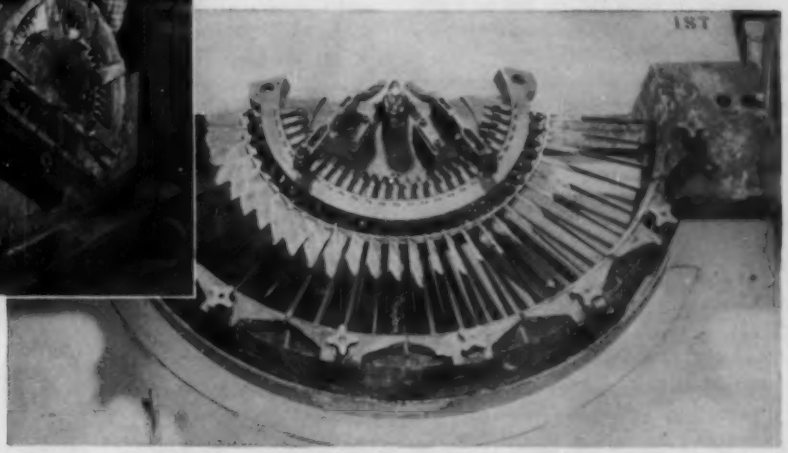
Machlett ML-5668*

INDUSTRIAL OSCILLATOR TRIODES

Each Curtiss-Wright J-65 turbojet engine uses 544 shrouded stator blades. Each blade must be positioned accurately and without physical distortion. Although brazing a single blade to the shroud ring is not difficult, it is quite a feat to perform rapid multi-blade brazing on a sustained production basis. Curtiss-Wright does just this in each of its three induction heating stations, each powered by two Machlett ML-5668 induction heater triodes.

*Machlett induction heater triodes are original equipment in over 75% of the induction heating equipment models now available in the 5kW to 100kW power output range. . . . Proof enough of Machlett electron tube quality and performance!





Top – ML-5668 Induction Heater Triode

Center – One of three induction heating stations used for production brazing of stator assemblies used in Curtiss-Wright's J-65 turbojet engine.

Bottom – Stator assembling jig for Curtiss-Wright's J-65 turbojet engine.

***ML-5668** Original Machlett electron tube design; heavy duty triode replacement for old design, light construction type 892 tube.

MACHLETT

FIRST IN INDUSTRIAL ELECTRON TUBES

MACHLETT LABORATORIES INC.
Springdale, Connecticut

Digests of Important Articles

Alloy Steels and Protective Coatings for Jet Engines

Digest of "Alloy Steels and Protective Coatings for Jet Engines", by H. J. Noble and W. H. Sharp, *S.A.E. Journal*, Vol. 63, November 1955, p. 57-61.

IN SELECTING STEELS for use at temperatures up to 1000° F. in aircraft engines, their formability, cost, and resistance to stress-corrosion must be considered as well as the more commonly determined properties. Where the use of expensive highly alloyed austenitic stainless steels is not justified, low-alloy steels with protective coatings, or martensitic chromium steels, may be used. Low-alloy steels extensively used in aircraft engines contain 0.30 to 0.45% C, 0.5 to 1.25% Cr, 0.2 to 0.55% Mo, and sometimes up to 1.8% Ni or 0.3% V.

Most organic protective coatings will not stand high temperatures, but one silicone resin with aluminum pigment has served well at 700° F.

Cadmium and zinc plates protect against corrosion up to 500° F., but cannot be used on steel subject to tensile stress, since these metals, when molten, are "stress-alloying" — that is, catastrophic intergranular penetration into the underlying steel takes place under stress. Thin nickel plate heated to 1000° F. improves the corrosion resistance of low-alloy steel, and certain organic addition agents can be used in the plating bath to increase the hardness. Chromium plate gives good resistance to abrasion, galling, corrosion, and oxidation up to 1000° F., without impairment of the fatigue resistance of the steel. The hardness may be reduced slightly by heating for a long period of time at 1000° F. Silver plate gives good resistfor a long period of time at 1000° F. but at higher temperatures oxygen penetrates to the steel, causing the plate to flake off.

A coating of nickel-phosphorus alloy deposited chemically without an electric current may be as hard as Vickers 1000, and have very uniform thickness on irregular surfaces if the solution is agitated during deposition. Its resistance to corrosion and oxidation is good up to 1000 F. Like nickel plate it should be treated to relieve hydrogen embrittlement.

Cadmium plated on nickel of sufficient thickness, and heated for diffusion into the nickel gives good resistance to galling and corrosion up to 1000° F. without creating susceptibility to stress-corrosion or stress-alloying. The combined coatings need be only 0.0005 in. thick, but careful control of the plating, and use of conforming anodes, are necessary. No failure of parts so plated has been reported.

Martensitic chromium steels, containing 0.10 to 0.15% C, 12.5 to 17% Cr, and sometimes 2% Ni, 3% W, or 0.5% Mo, can be hardened by heat treatment, and have fairly good resistance to oxidation and corrosion. When quenched and tempered below 900° F. they have over 190,000 psi. tensile strength, over 140,000 psi. yield strength, over 15% elongation, over 5% reduction of area in tension, and over 15 ft-lb. Izod impact resistance. They are thus excellent for service below 800° F., but they soften greatly above 1000° F. The grade containing 2% Ni and 3% W is about 10,000 to 20,000 psi. stronger at all temperatures than the Cr steel without those additional alloys. These steels are less costly and more stable between 600 and 800° F. than precipitation hardening austenitic stainless steels.

Cleanness and a ferrite-free structure are desirable for high fatigue strength in these martensitic steels. High surface finish without traces of scale or foreign particles gives superior rust resistance, and is attained by heat treating in hydrogen or pickling or abrasive blasting, with final polishing.

These steels are susceptible to stress-corrosion cracking. Double tempering, or tempering between 300 and 500° F., delays the occurrence of such failures. Shot peening may also be helpful, but passivation or other acid cleaning is not. Failures start at corrosion pits and progress intergranularly in the martensitic chromium steels. The resistance of such steels to this type of failure depends on hardness and tempering history, and is greatest in the steels with highest tempering temperatures.

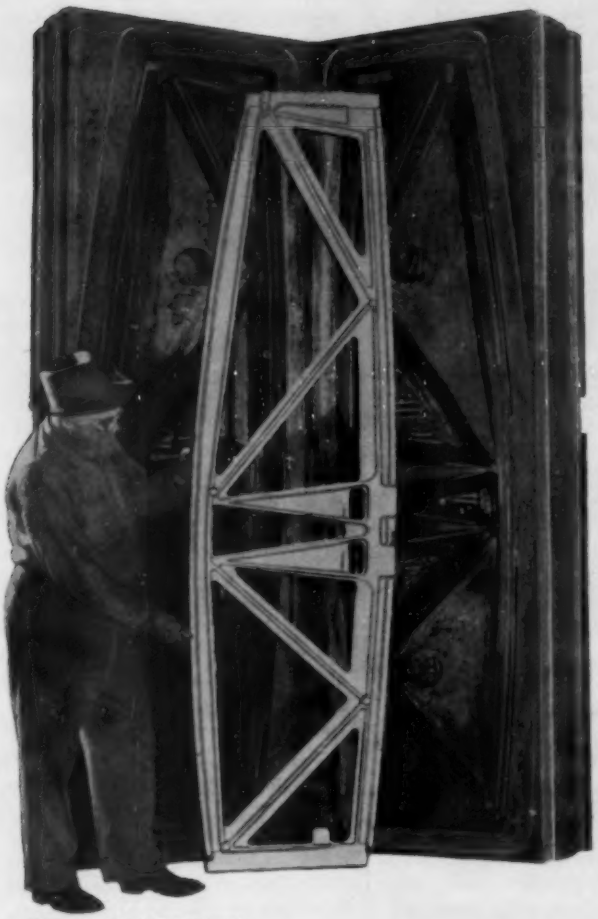
G. F. COMSTOCK

Powder Metals for Reactors

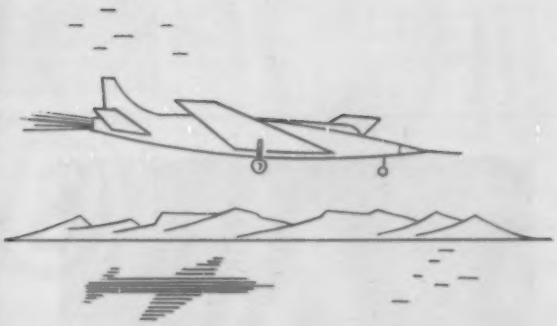
Digest of "Application of Powder Metallurgy in Nuclear Engineering," by H. H. Hausner, presented at 12th Annual Meeting of Metal Powder Assoc., April 1956, 16 p.

POWDER METALLURGY'S role in the development of nuclear power seems assured. Powder metals may be used in the preparation of reactor metals and they may also be applied in the form of cermets.

The author discusses the effect of irradiation on solid materials, showing how it hardens metals, increases strength, decreases ductility, and increases resistivity. This is explained in terms of lattice defects created in the structure. The nature of metal powders and the effects of pressing to yield the green compact



COURTESY ALUMINUM COMPANY OF AMERICA



Increase Production

with FINKL DIE BLOCKS

...the aircraft industry does!

These two 14 x 35 x 114" FX die blocks, made from Finkl electric furnace steel, and weighing 15,800 pounds each, are used for producing precision aluminum landing gear rib forgings.

Finkl FX die blocks are noted for their long production runs and economy because:

- FX covers the full usable hardness range from Temper H (477-444 BHN) to Temper 4 (293-269 BHN).
- FX produces the greatest number of forgings per impression because its well balanced alloy content offers uniform hardness and freedom from temper brittleness. Relatively high tempering temperature promotes ductility and elimination of residual stresses.
- FX Special Machining Quality appreciably reduces shanking and sinking time.

These proved advantages can also mean savings to you with more pieces per die and better deliveries to your customers.

Save money by talking to a Finkl representative the next time you are considering die blocks or forgings.

DIE BLOCKS · FORGINGS · HOT WORK STEELS · ELECTRIC FURNACE STEELS

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Powder Metals . . .

and of sintering to rearrange the atoms are presented in clear terms.

The new metals employed are beryllium as moderator, uranium and thorium as fuels, and zirconium as a material of construction. The powders of these four metals are generally to be used in a high state of purity. Beryllium, being brittle, can be mechanically pulverized to 20μ. The others are ductile, but, since they all form hydrides, they can be created to size in that form and then reconverted to metal, yielding powders of 5 to 50μ size. Calcium reductions are also employed, while zirconium can be made electrolytically or by a leaching method and thorium electrolytically or by sodium reduction. Great care must be observed in handling these metals, since all but zirconium are toxic and all but beryllium are pyrophoric. Working with gloves from outside of closed chambers having inert atmospheres is required.

These powders differ in their compacting quality. Beryllium compacts well to a low density but not to a high density. Sintering, even close to the melting point, never results in complete densification. Vacuum sintering at 2190° F. does develop high density while argon atmospheres will not produce as high a density. This the author attributes to the new factor of evaporation and condensation, not generally a part of metal compact sintering. The sintered metal can be cold rolled about 10%, then annealed and cold rolled again, but to be really dense, the metal should first be formed by hot pressing.

Zirconium is well suited to powder metallurgy techniques. Most powders compact easily, and sinter to full density. The use of hydride compacts permits activated sintering. Decomposition of hydride and bonding of metal take place at similar temperatures, and active zirconium, freshly freed of hydrogen, bonds together rapidly in the compacted form.

The situation is somewhat different with uranium hydride powders since the hydride does not compact to a high density and high strength; however, experiments in hot compacting show that uranium powder can be brought to essentially full density by compacting at 1110° F.

Satisfactory thorium powders can be prepared by several methods but the decomposed thorium hydride powder produces the most perfect sintered thorium compacts.

The technique of compacting and sintering alloy powders is identical with that used to form pure metals by metallurgy. Sintering, however, takes somewhat longer, since the diffusion of one metal into the other takes time. Powder metallurgy is particularly advantageous in making alloys if the metals have widely different melting points and different densities.

Certain types of reactor fuel elements can be fabricated in the form of cermets such as uranium oxide in a matrix of aluminum or stainless steel. Fuel elements can be made from this type of material which will better withstand irradiation and corroding conditions.

LINCOLN T. WORK

SUNDSTRAND AVIATION
stabilizes
bearing components
with Cincinnati
Sub-Zero
SUNDSTRAND
Absolute stabilization of vital steel and bronze bearing components helps insure the dependability of SUNDSTRAND AVIATION parts.
Aircraft bearing parts are "quick-aged". . . toughened . . . and stabilized in a CINCINNATI SUB-ZERO 7SR-120-26 Chilling Unit which affords SUNDSTRAND high capacity in minimum floor space. They also like the advantage of faster heat control with the Convection Fluid Agitator, which effectively reduces chilling time.
Write today for the free complete-line catalog . . . or outline your own special low-temperature requirements for a no-obligation survey.
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Inducto

THE INDUCTION MELTING FURNACE WITH PRECISION CONTROL

Here is induction metal melting equipment at its best!

NEW FURNACE DESIGN . . . Sturdy, welded construction eliminates distortion and increases lining life.

NEW COMPACT CONTROL . . . Totally enclosed panels include built-in capacitor bank, selector switches and high frequency transformer. Compact design for efficient operation and shipped completely assembled.

WATER COOLED LEADS . . . Introduced through trunion. No furnace pits necessary. Shorter leads mean more operating efficiency.

SELECTOR SWITCHES . . . Mounted on lower front of control panel for maximum accessibility and minimum bus losses. You can change furnaces in a few seconds.

For details, write for our Bulletin 70.

INDUCTOTHERM CORPORATION
INDUCTO
412 ILLINOIS AVE.

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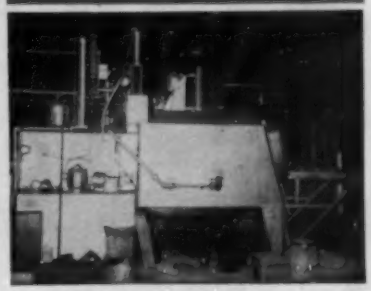
GOOD USED EQUIPMENT AT REAL SAVINGS TO YOU!



IPSEN CARBONITRIDING FURNACE!
Excellent Condition Complete with Atmosphere Generator

- We Buy—Sell—Lease—Rent!
- Specialists in Heat Treating—Melting — Forging — Plating — Cleaning Equipment.
- 3000 Furnaces.
- Modification to Your Specs.
- Money Back Guarantee!
- Immediate Delivery!
- 16,000 Sq. Ft. Heated Warehouse
- Warehouses in Major Cities.

Sales representatives wanted in all principal cities.
PLEASE SEND YOUR REQUIREMENTS OR CALL COLLECT
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METAL TREATING EQUIPMENT EXCHANGE, INC.
9825 GREELEY ROAD
DETROIT 11, MICHIGAN

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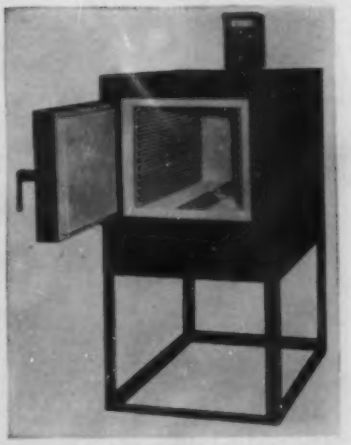

More than two thousand satisfied users WILL TESTIFY YOU

SAVE 3 WAYS WITH A LUCIFER FURNACE

1—Save on First Cost

CHECK THESE PRICES

Furnace Size	2000°	2300°
6x 6x12"	$ 500.00	$ 600.00
9x 9x18"	750.00	850.00
12x12x24"	1000.00	1100.00
18x18x36"	1500.00	1600.00

Complete with 100% automatic electronic controls.

2—Save on Man Hours

Less operator attention needed—Lucifer controls are EXACT. They reach SPECIFIED heat rapidly and retain SPECIFIED temperature without variation. No special experience required when you use a Lucifer Furnace.

3—Save on Maintenance

Finest refractory materials are built into Lucifer Furnaces for better, more efficient heat retention. Elements are guaranteed, long lived, trouble free.

WRITE FOR FREE LITERATURE, specifications and price list of Lucifer Furnaces in wide range of sizes—top loading and side loading types. Engineering advice without obligation. Write, wire or phone today.

LUCIFER FURNACES, INC.
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dyna-trol ELECTRIC FURNACES

MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P46	4½"x4½"x6"	$90.00	$110.00
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

Automatic Controls Available on all Models

MODEL P2472-1

MODEL P-79

- Infinite zone temperature control.
- Zone temperature indication by Pyrometer Selector Switch.
- Automatic hold and cut-off instrument available.
- Patented element holders.
- Infinite variety of time-temperature curves obtainable.
- Rugged construction. Highest quality insulation used

OVER 40 STANDARD MODELS • WRITE FOR LITERATURE

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INDUSTRIAL DIVISION
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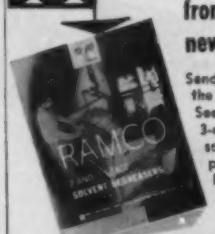
Q A METAL PARTS CLEANING PROBLEMS?

Get the answers RIGHT from RAMCO'S new BULLETIN!



Send for your copy of the Ramco Bulletin. See how Ramco 2- and 3-dip degreasers can solve your metal parts cleaning problems safely, efficiently, economically! Send today!

RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd., New York 39, N.Y.

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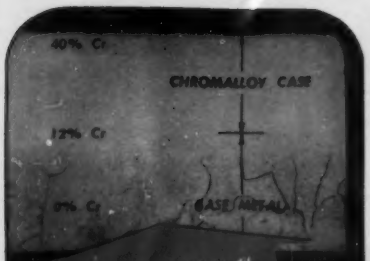

Photomicrograph shows diffusion structure of the CHROMALLOY Case. At the surface the chromium content is 35% to 45%.

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CORROSION

CHROMALLIZING diffuses chromium into the surface of iron and steel parts, providing the corrosion resistance of stainless steel and the wear resistance of chromium carbides. CHROMALLOY Case cannot chip, peel or flake.

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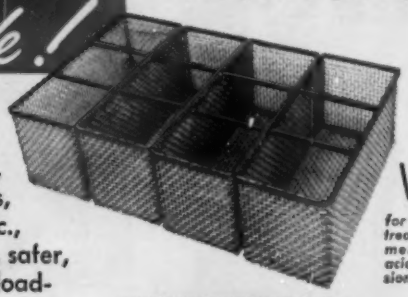
all styles, metals, weaves ...any size, quantity!



Wiretex engineers Baskets, Muffles, Screens, Fixtures, Grids, Racks, etc., to insure easier, safer, loading and unloading; greater space saving, better draining and cleaning.

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Specialists in Processing Carriers Since 1932.

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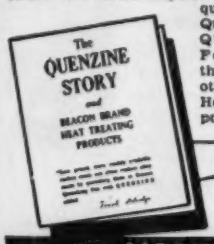
Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



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RUST-LICK
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Grade "B"
FERROUS METAL PROCESSING

Eliminates . . .

Rust
Fire Hazards
Toxicity
Dermatitis
Degreasing

Write for free sample and brochure
Specify Grade "B"

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✓ A HEAT TREATING CONTAINER PROBLEM WE CAN'T SOLVE

We are specialists in the design, engineering and manufacturing of equipment for handling parts through heat treating, quenching, pickling and related operations. Let our broad experience serve you! We can supply baskets, trays, fixtures, carburizing boxes, retorts or furnace parts designed to meet your specific

THERE'S A STANWOOD REPRESENTATIVE NEAR YOU!

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Taber Stiffness TESTER

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Tests wear resistance of metal, plastic, paint, rubber, leather, paper, foil, etc. With average technical experience, anyone can make a scientific, comparative abrasion resistance test with this instrument.

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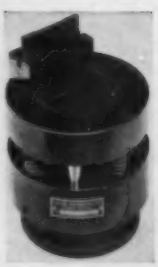
FOR TEST SPECIMENS . . .



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TENSILE TEST BAR
MPA STANDARD
10-51

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- Green Strength
- Bushings
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- Stepped Parts

Complete design facilities for dies or subpress units to press unusual shapes in lab presses.

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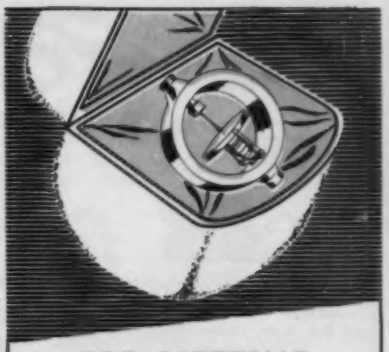

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SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

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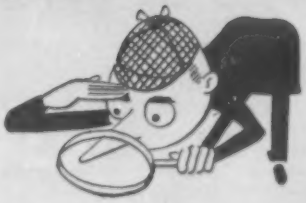

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This new service on used heat treating equipment is completely without obligation to you. To receive the latest availabilities just drop us a line requesting to be placed on our mailing list for a monthly digest. What are your production requirements?

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This free listing is yours at no cost. CHECK WITH HOLDEN FIRST. Proven MONEY MAK-ER PRODUCTS.

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Inspection Demagnetizing or Sorting PROBLEMS?

SOLVED with

MAGNETIC ANALYSIS MULTI-METHOD EQUIPMENT

Electronic Equipment for non-destructive production inspection of steel bars, wire rod, and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

Over 80 installations in steel mills and fabricating plants.

MAGNETIC ANALYSIS SPECIAL EQUIPMENT

Electronic Equipment for non-destructive production inspection of both non-magnetic stainless and high temperature steel bars and tubing—seamless or welded—as well as non-ferrous bars and tubing. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed 200 ft. per minute.

Over 30 installations in mills and fabricating plants.

MAGNETIC ANALYSIS COMPARATORS AND METAL TESTERS

Electronic Instruments for production sorting both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

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Electrical Equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETIC ANALYSIS MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

TRADE MARK

For Details Write:

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"THE TEST TELLS"

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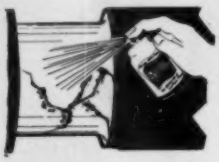
DYELINE INSPECTION PROCESS



Dyeline—a new two-stage inspection process for all non-porous materials. No skilled operator or expensive equipment necessary! Just spray Dyeline, follow with Dyeline Detector, and the exact location, type and extent of defects appear sharply and clearly on an opaque background! No solvent required—water removes Dyeline immediately.

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ALSO:

ZIP SPEED LACQUER—Identifies all materials with a quick color-coding process.

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ZIP BELT LUBE—Prolongs belt life; promotes safety and speed.

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TEMPERATURE PRESSURE LIQUID LEVEL

EQUIPPED WITH
SEALED MERCURY CONTACT SWITCHES
"The Contact That Never Requires Cleaning"

FOR OUTDOOR, INDOOR OR EXPLOSIVE ATMOSPHERES

Our engineers are at your service—send in your control problem or

Write for catalog No. 857

THE MERCOID CORPORATION
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THE NEW

DERMITRON

NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST—ACCURATE
COMPACT—PORTABLE
DIRECT-READING

- *Sorts Metals and Alloys*
- *For Metals on Metals*
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You can now have 100% inspection of production of nearly any possible coating on almost any base—including the first and only accurate, direct readings of such combinations as zinc, cadmium, copper on steel; silver on brass; copper on zinc; anodizing on aluminum; organic coatings on non-ferrous metals—without the use of chemicals.

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for ALL Industrial Uses

- Degreasing
- Anodizing
- Pickling
- Plating
- Heat Treating
- Heavy Industrial Types

ANY SIZE AND SHAPE • ANY DUCTILE METAL

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THE C. O. JELLIFF MANUFACTURING CORP.

SOUTHPORT • CONNECTICUT

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Thickness Testing from One Side

Rapid, Accurate, Non-Destructive

VIDIGAGE®

14" or 21" Cathode-Ray Screen with direct-reading scales between 0.005" and 2.5"; accuracy 0.1% to 1.0%.

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Portable Thickness Testers for ranges from 0.020" to 4" or 0.060" to 12" of steel; accuracy up to 1.0%.

Detect Laminar Flaws and Lack of Bond

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Specializing in Ultrasonics Since 1946

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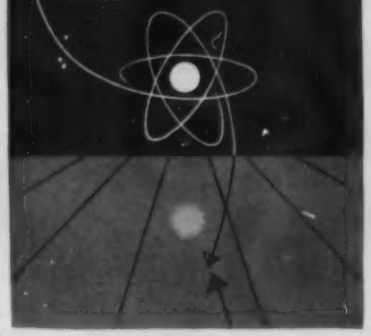
equips you to Electroplate Precious Metals with



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TECHNIC BIBLIOGRAPHY

Technic publications, authoritative in our field: "Electroplated Gold"; "Precious Metal Electroplating Data: Gold, Rhodium, Palladium, Platinum, Silver, Nickel"; "Electroplated Platinum"; "Electroplated Palladium"; "Electroplated Rhodium"; "Analysis of Gold & Gold Alloy Solutions".

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- "How-to" stories on tough lubrication applications
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Accurate test specimens machined from sheet and plate materials .0005 to .500 in., in less than 3 min.

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Horse Plain Rd. • New Britain, Conn.

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HARDNESS TESTING MACHINES
made by the Alpha Co. of Sweden and available from our stock at New Rochelle

Never approached in ACCURACY AND CONSTANCY of calibration . . . at the standard 3000kg test load: . . . maximum error plus or minus 2½ kg

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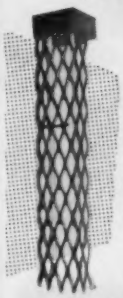

- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

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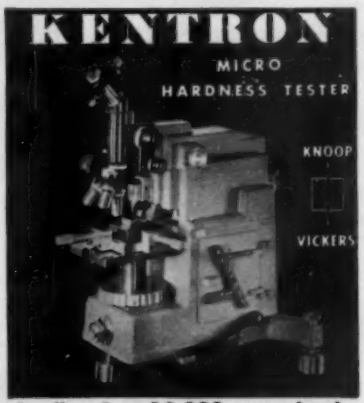
MICRO HARDNESS TESTER



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Mirror-bright finish in any thickness directly from the bath.
Patent Pending

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Crystal-clear solution that produces mirror-bright deposits.
Patented

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Brilliant, fine-grained, non-tarnishing deposits.

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- PHOSPHATIZING WASHERS • ALKALINE WASHERS
- FLOW COATING SYSTEMS • "SPOTLESS" DRYERS
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We will be happy to send a sales engineer to help you with any metal cleaning equipment problem. Complete information on request.

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SINCE 1922

Aluminum and Zinc

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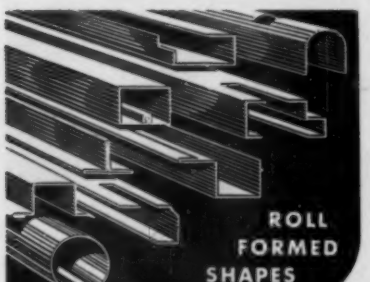

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ROLL FORMED PRODUCTS CO.

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New pocket size
Ferritic **ELCOMETER**

Answers need for rapid testing. New precision instrument shows directly on scale the per cent of Ferritic content of weld, replacing time-consuming, destructive laboratory analysis. Enables you to make rapid, on-the-spot, nondestructive tests for iron content.

Accurate readings in all positions. Needle locking device assures correct readings. Balanced in all planes. Sturdily constructed. Comes in tough leather case. Fits in pocket.

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FERRO CORPORATION

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Swift

SOLUTIONS TO YOUR METAL TREATING PROBLEMS!....

SWIFT BLACK

Activanium Blended— Positive blackening of every ferrous metal and alloy!

NOT GRAY
NOT FADED
NOT MOTTLED
BUT RICH, DARK, UNIFORM
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METAL CLEANING PICKLING and PLATING COMPOUNDS

Acid additives, brighteners, bright dips and chromate conversion coatings!

Send today for literature and technical data sheets.

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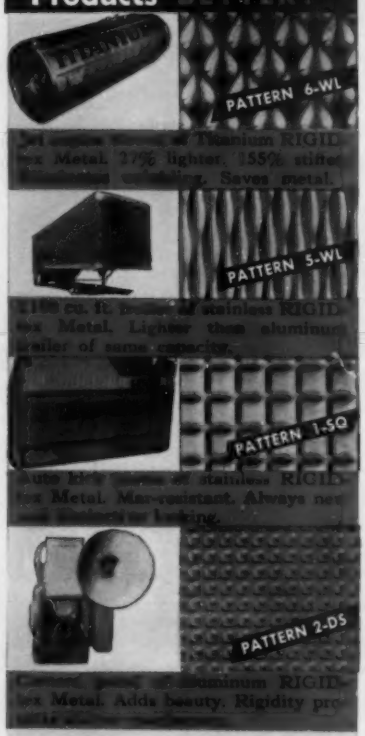
RIGID-tex METAL
Makes all these Products BETTER!



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RIGID-tex METAL
IT'S RIGIDIZED

RIGIDIZED METALS CORP.
Representatives in Principal Cities

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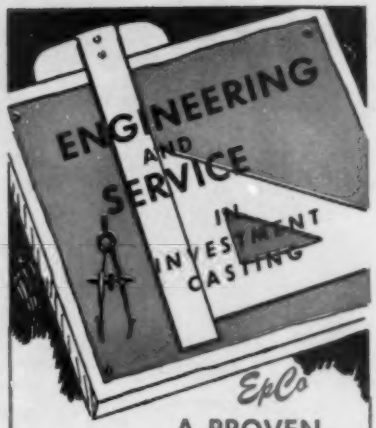

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STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

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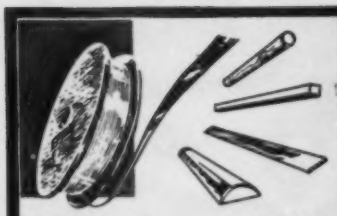

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Other Non-ferrous Alloys
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- No acid pickle or bright dip.
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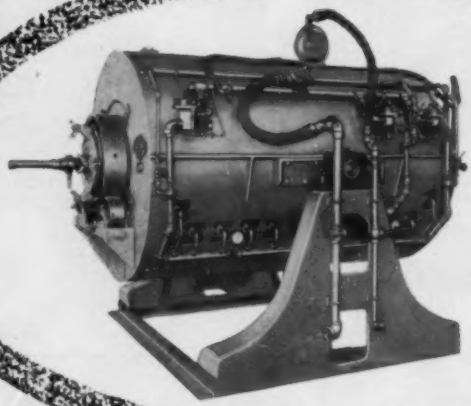
LOWEST COST CARBURIZING IN AGF ROTARY CARBURIZERS



AGF Rotary Carburizers are available in sizes to suit your requirement —large or small.

Model No. 4 illustrated handles up to 1200 lbs. per load.

YOU GET THESE ADVANTAGES:

Lowest investment cost for heat treating capacity

The relatively simple design and construction of the AGF Rotary Carburizer enables you to purchase more heat treating furnace capacity per dollar expended than can be obtained with any other type of furnace.

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Gentle tumbling of the work as the retort rotates, eliminates "point of contact" case variations which can occur in furnaces when parts remain stationary. Every single piece is uniformly heated and exposed to the action of the atmosphere gas.

Versatility increased

The AGF Rotary Carburizer is a versatile batch type furnace that can quickly convert from one process to another for different work charges. Clean hardening, annealing, normalizing, etc., can be accomplished without any modifications to the furnace.

Proven acceptance

Leading manufacturers of roller bearings, ball bearings, conveyor chains, small parts as well as commercial heat treaters have chosen the low cost AGF Rotary Carburizer method. Let us explain its particular advantages for your application today.

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High-Vacuum Melting of Metals

Digest of "Vacuum Melting, Heat Treating, and Processing", by David N. Reece, presented at Educational Program of Los Angeles Chapter, ASM, November 1955, 19 p.

THE USE of high vacuum in the melting and purification of metals dates back 50 years or more, and with the impetus lent by wartime needs now occupies an increasingly important position in metallurgy.

There are several important components of conventional vacuum systems. Ordinary mechanical pumps operate effectively from atmospheric pressures down to 1 mm. of mercury, below which efficiency decreases sharply. The diffusion pump was developed for effective pumping below the level of 1 mm. – the so-called "high-vacuum" range. There are two types of pumps, the booster diffusion pump, for work in the range from 0.1 mm. to below 0.001 mm., and the high-vacuum diffusion pump, which operates best between 0.001 mm. and 0.00001 mm. (0.01 micron), or even lower. Both types of diffusion pumps make use of vaporized oil or mercury molecules directed by means of jets to drive, or pump, the air molecules out of the chamber being evacuated. Mechanical and diffusion pumps are often used in combination to create high vacuums.

Vacuum melting is probably the best known of the applications of high vacuum to metals. A more pure, homegeneous and better controlled metal is produced by vacuum than can generally be obtained by air melting. Induction heating is especially well suited to vacuum melting, since it provides very high temperatures, delivers its heat energy directly to the metal being melted with minimum heating of surrounding materials, and provides an effective means of stirring. Induction furnaces vary in size and arrangement, but most now have the same basic group of components. These include the induction furnace mounted inside a vacuum chamber, a charging chamber, a high-vacuum pumping system, and power supply. High-production units are equipped with airlocks for continuous charging of the furnaces and removal of the mold. (*Continued on p.* 172)

Tool Steel Topics

BETHLEHEM STEEL

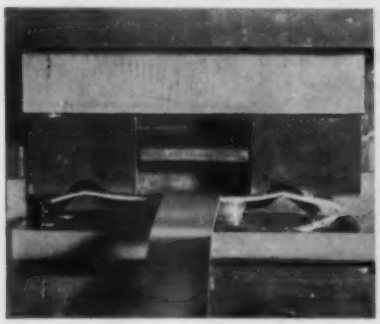
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation

Maker of Beer-Can Openers Likes Economy of Lehigh H

Cadet Manufacturing Corp., San Antonio, Texas, needed a strong, long-wearing die for the economical manufacture of beer-can openers. They put the problem up to their local tool-steel distributor, Earle M. Jorgensen Co., who recommended Bethlehem Lehigh H. "Our experience with this air-hardening grade has shown us how it stands up," the Jorgensen people said. "It's resistant to wear and, besides, has low distortion in heat-treatment."



The die was produced by Precision Manufacturing Co., San Antonio, and heat-treated by Cook Heat Treating, Houston. It was placed in service in a 56-ton press in Cadet's shop, where it was fed C 1035 cold-rolled strip, 0.065 in. thick. Performance was excellent, the die performing economically at the high speed at which the press operated. About 800,000 pieces were produced between grinds.

Lehigh H, our high-carbon, high-chromium grade of air-hardening tool steel, is ideal for tough assignments because of its outstanding wear-resistance and toughness. It is well known for its minimum distortion in heat-treatment, and high compressive strength.

TYPICAL ANALYSIS

Carbon 1.55	Molybdenum 0.80
Chromium 11.50	Vanadium 0.40

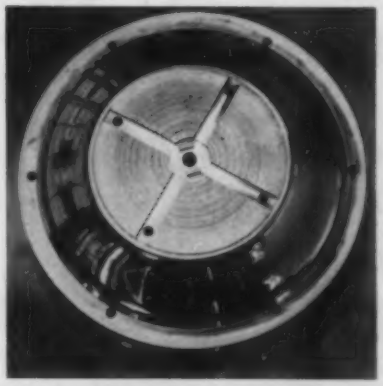
Look into the advantages of Lehigh H by giving it a try. Chances are good that your local Bethlehem tool steel distributor has Lehigh H in stock. Give him a call.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Follow Up With Temper When Drilling Hardened Tools

When necessary to drill holes in hardened tools or dies to incorporate dimensional changes, such drilling is usually done with a triangular drill made of a cast stellite or a sintered carbide. This type of drill operates by generating frictional heat sufficient to locally anneal the steel, so that the cutting edges can scrape the metal away in the path of the drill. All tool steel grades, regardless of how high the hardness developed by heat-treatment, can be drilled in this manner.

It is obvious that such a procedure will produce stresses in tools or dies which, because of heat-treatment, already contain residual stresses. It is important, therefore, that the drilling operation on hardened tools always be followed by a tempering operation. Tempering should be carried out at a temperature equal to, or slightly below, the final temper used in the original heat-treatment operations.



Lustre-Die Provides High Sheen When Making Plastic Parts

This core for a plastic injection mold, made by Interstate Mold & Hobbing Co., Union, N. J., is for use in manufacturing a decorative bowl for household use. It is made of Lustre-Die, an electric-furnace steel of well-balanced analysis, which we alloy-fortify to increase its depth of hardenability and mechanical properties. Use Lustre-Die when you want unusually high sheen on plastic parts. You'll like it.

Highly accurate

2-MINUTE CARBON *analysis*

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Determine carbon content in just 2 minutes! No complicated mathematics; eliminates costly time-consuming routines. Accurate analysis of borings, mill chips, crushed samples, pellets, etc. Dietert-Detroit testing equipment widely used in company laboratories and institutions of every description for over 18 years.

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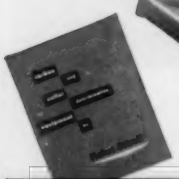

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Vacuum Melting . . .

Vacuum melting helps to improve alloy characteristics and performance in several ways. It prevents reaction between atmospheric gases and the melt, promotes dissociation of gas-metal compounds and elimination of gases, accelerates reactions which have gaseous products, and eliminates the need for slag or flux. The result is virtual freedom from inclusions, elimination of gaseous and gas-metal compounds, and better control of chemistry.

Fatigue properties are improved by vacuum melting. In comparing air melted versus vacuum produced S.A.E. 52100 bearing steel in rotary beam tests, Vacuum Metals Corp. reported average failure life of 15,000 cycles for air melted material, and 10,000,000 cycles for vacuum melted steel. Vacuum melting has also been widely and successfully used for the production of heat resistant alloys for high-temperature engine applications, including M-252, Hastelloy R-235 and Waspalloy. Cleaner and sounder ingots lead to high yields, and closer control of chemistry promotes ductility, high stress-rupture strength, and better hot workability.

Although induction melting is the most common technique in vacuum production of metals, arc melting is preferred for materials which have very high melting points, or which are reactive with conventional crucible materials. Molybdenum, tungsten, titanium and zirconium are produced by the consumable electrode method. An electrode is fabricated of the material to be melted, which is then melted by its own arc into a vertical water-cooled copper crucible or mold. One disadvantage is the fact that only a small amount of metal in the mold is molten at any one time, making proper mixing difficult. Consequently a common practice is to put the materials through two complete melting cycles. The first consists of melting a pressed sponge electrode in inert atmosphere, casting into ingots, and using these ingots as electrodes in the second melting under high vacuum.

Skull melting is basically an arc melting technique, using nonconsumable tungsten electrodes under inert atmosphere, in which the melt-

(Continued on p. 176)

Titanium Cylinders drawn in one stroke on the same die

Titanium, magnesium, zirconium, stainless and aluminum 2024 are deep drawn in one operation by Brooks & Perkins.

Cost of staging dies and intermediate anneals is eliminated.

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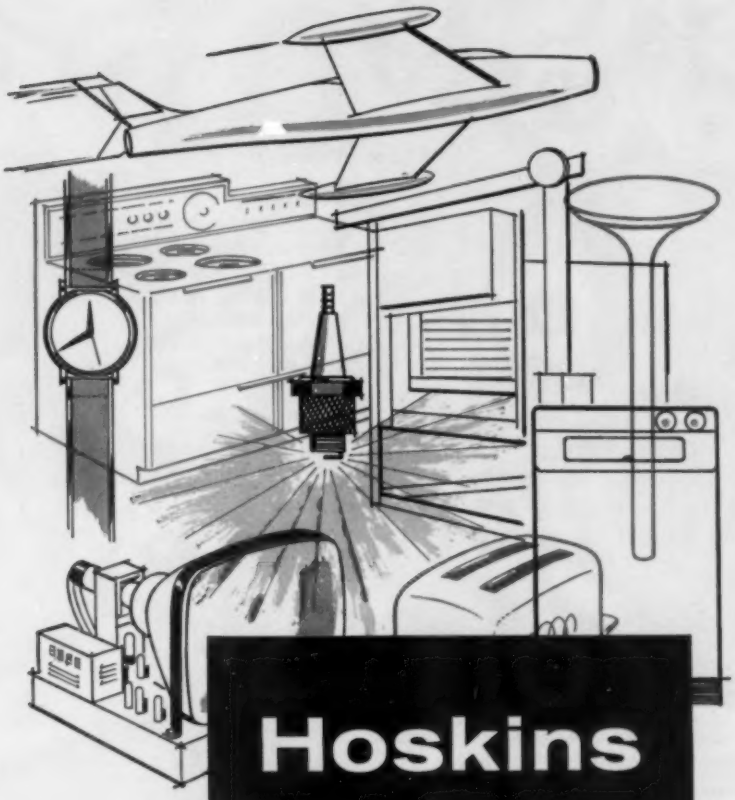

Hoskins Custom Quality Alloys

CHROMEL-A is the original 80-20 nickel-chromium heating element alloy. Unequalled for durability and uniformity of resistance, it gives dependable top performance in electric ranges, furnaces and many other devices requiring heating units capable of operating at high temperatures under adverse conditions.

CHROMEL-ALUMEL thermocouple alloys possess finer accuracy and greater durability than any other known base metal materials. Made exclusively by Hoskins, they are the accepted standards for controlling heat treating operations up to 2300°F. and measuring exhaust temperatures of jet aircraft engines.

COPEL is a fine copper-nickel alloy which delivers superior performance on a wide range of "cold" resistor applications. Its controlled low coefficient of resistance, mechanical stability and high corrosion resistant properties recommend its use in precision instruments and many types of electronic devices.

ALLOY "502" is one of several special mechanical-purpose alloys developed and produced by Hoskins for diversified applications. Highly resistant to heat and corrosion, it is used with outstanding results as structural members for industrial furnaces, enameling hooks, heat treat fixtures, wire cloth, etc.

ELECTRODE WIRE produced by Hoskins is used with confidence by all leading spark plug manufacturers. Each of the several grades developed for such use is made by special melting and processing methods which result in extremely close control over alloy composition and assure dependable, long-life service.

Serving the progressive needs of industry since 1908

Only one of its kind— Designed and built by Hoskins, this special instrument provides accurate means of measuring temperature coefficient of resistor wire and ribbon. As part of our complete metallurgical research and development facilities, it is one more reason why you should "look to Hoskins first for the finest in quality controlled alloys!"

DEVELOPING and producing custom quality alloys is a specialty at Hoskins. And it has been for nearly fifty years. Some, like Chromel, have been responsible for the birth and growth of entire industries. Others, like Copel, were developed to permit continued improvement in the design and operation of countless different end-products. Regardless of their application, however, each in its particular field is unsurpassed for durability, performance and dependability in service. And each is the result of specialized research activity devoted to the development of new and finer alloys to help make your products better.

Want more detailed information on Hoskins alloys, facilities and services? It's yours for the asking without obligation.

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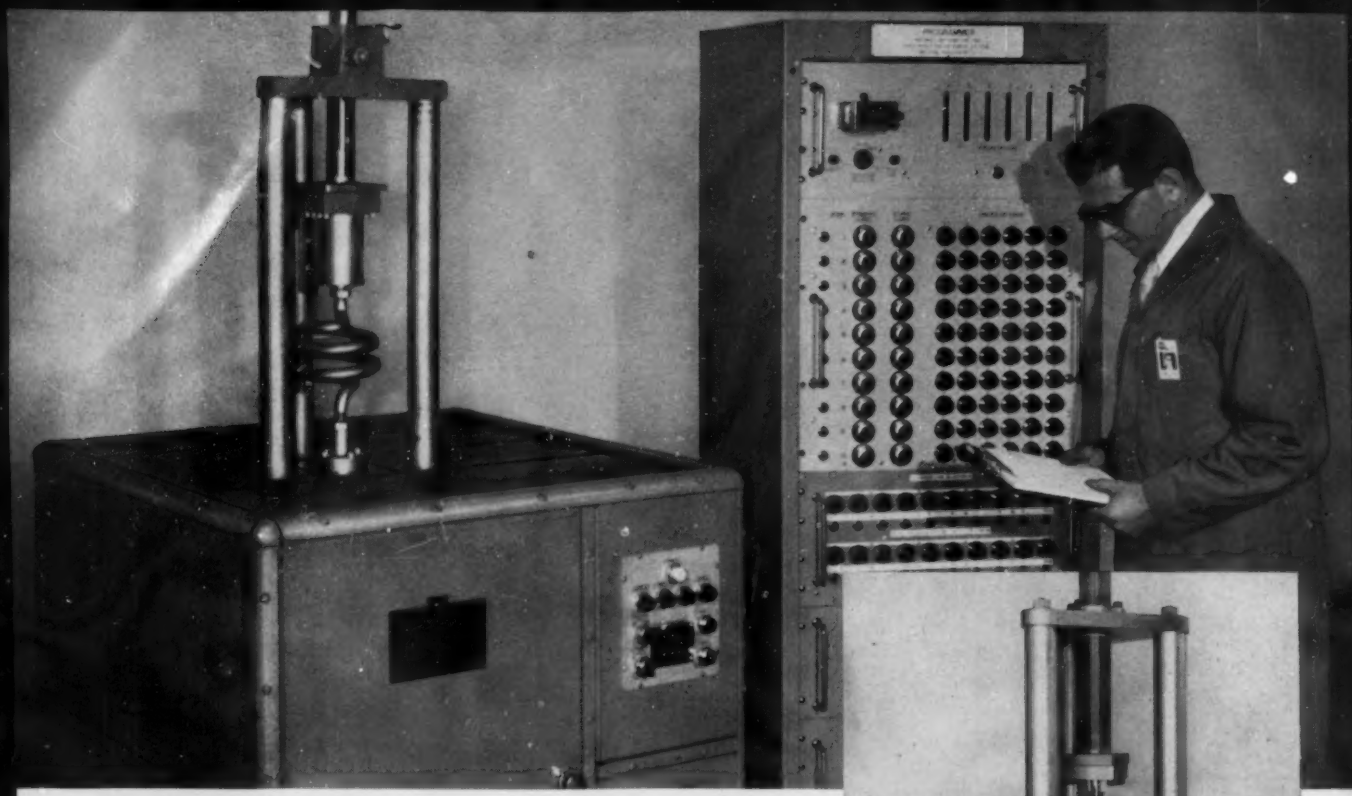


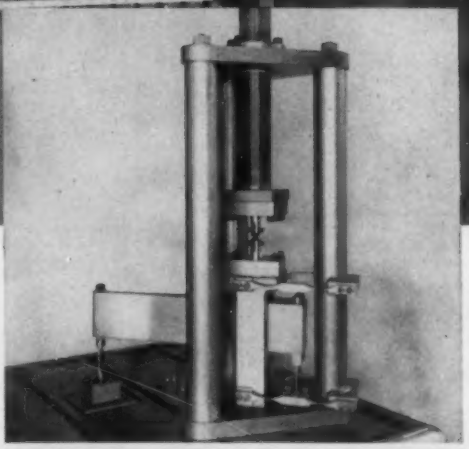
The Baldwin SF-1-U Universal Fatigue Machine shown here is being controlled by the Baldwin Programmer at its side. Entire sequences of varying static or dynamic loads can be run off, all in one automatic operation.

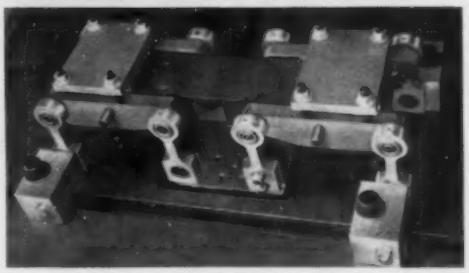
BALDWIN MAKES EVEN SEVERE, PROGRAMMED FATIGUE TESTS AN ACCURATE, AUTOMATIC OPERATION

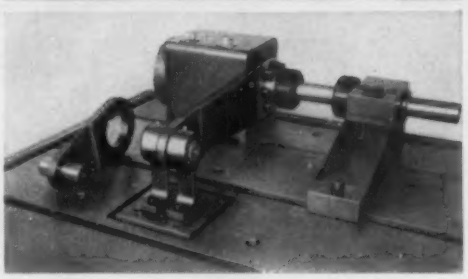
Here is simulated service testing with flexibility, accuracy and ease never before possible! Baldwin Universal Fatigue Machines have capacities ranging from 50 lb. to 10,000 lb. With proper fixtures, almost any combination of static and dynamic stress may be obtained. Load accuracy is within ±2% of load or 0.4% of capacity, whichever is greater.

Add a Baldwin Programmer to your Baldwin SF-1-U Fatigue Machine, and you have testing automation! Complete test sequences can be set up on the programmer controls and run off on the fatigue machine without supervision. Varying static or dynamic loads, for any predetermined number of cycles are possible. Loads can be changed at approximately 500 lb. per min.

For the best in testing, see Baldwin first . . . choose from a complete line of equipment for testing compression, tension, creep, fatigue, impact or torsion. Write today and ask to have a Baldwin representative call on you.







Fixtures for Universal Fatigue Machines include (top to bottom) amplification, bending and torsion.

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for Super Nickel, Chromium, and Cobalt-base Alloys

Now, for manufacturers of high creep strength alloys or high-temperature super alloys, Sylvania offers hydrogen reduced and fully sintered molybdenum pellets to help meet the most exacting alloy specifications.

Sylvania Molybdenum Pellets are designed specifically for use in vacuum melting operations. They provide a readily available source of molybdenum having a purity of at least 99.5%—typical purity is 99.85%. This constant high purity simplifies the calculation of additions to each melt as the usual variations of purity and gas content are eliminated. By maintaining a high density, the gas content of the pellets is kept well below that acceptable for vacuum melting. In addition, the compact uniform size of the pellets (1″ in diameter by ½″ high) facilitates weighing and charging to the melt.

When you use Sylvania Molybdenum Pellets, you benefit in other ways, too. Their continuous availability means you can plan your production schedules on a long range basis. Further, their pricing stability permits you to price your own product without having to worry about fluctuating raw materials costs.

Your Sylvania sales engineer will be glad to discuss your molybdenum requirements or the high-purity tungsten available in sintered ingot form for vacuum melting. For further information, write to:

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Type ID—20-lb., 20 Kw.
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Vacuum Melting . . .

ing is done in a metallic bowl or skull of the same composition as the metal being melted, avoiding contamination.

Vacuum is also being used more and more in annealing, heat treating, brazing and sintering. An excellent example is in the heat treatment of titanium and its alloys, which may be seriously embrittled by high hydrogen content. Treatment in vacuum prevents contamination from the atmosphere and actually removes substantial quantities of hydrogen from the metal through dissociation of hydrides.

Vacuum is applied to the processing of nuclear reactor materials where purity and exactness of composition are highly important. Mr. Reece envisions a time when certain reactor materials will be melted, rolled, machined and formed in an evacuated working area, where complex manipulators or robots will perform the tasks now done by hand.

W. V. WARD

Corrosion Resistance of Sprayed Aluminum and Zinc

Digest of "Sprayed Aluminium and Zinc in Corrosive Environments", by R. E. Mansford, *Corrosion Technology*, Vol. 3, October 1956, p. 314-316.

METAL SURFACES can be protected against corrosion by sprayed metal coatings. The sprayed metal may be anodic or cathodic to the base metal in the environment for which protection is required. Ideal protection is provided by an anodic coating due to the tendency of the corrosion products to seal the pores of the coating. Metals that are usually cathodic to steel, such as copper and its alloys, nickel, Monel, and stainless steel, must be applied in greater thicknesses than anodic metals and often require a buffing or grinding treatment to seal the pores. They are therefore used for special applications where their corrosion resistance warrants the cost.

Aluminum and zinc provide excellent protection in a wide variety of corrosive atmospheres and natural

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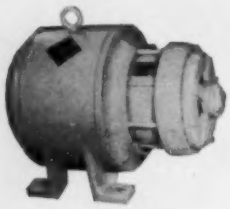
If you have a cleaning problem on metal parts from bearings to crankshafts General Ultrasonics can help you.



New 2KW Generator

For large ultrasonic applications, we are furnishing our new (non-electronic) 2KW motor-alternators. For tanks up to 100 gallons, the 2KW with simple push-button controls will power 6 of the D-52 Sonicells shown above.

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ULTIMATE IN ULTRASONICS

Sprayed Coatings . . .

waters and, since both metals are usually anodic to steel, only moderate thicknesses need be applied and sealing treatments are rarely necessary. Almost 90% of the work protected by metal spraying is coated with aluminum or zinc. Lead, tin and cadmium are used occasionally.

Aluminum – In most environments sprayed aluminum coatings give cathodic protection to a steel base at discontinuities such as pores and scratches. They give excellent protection in normal industrial atmospheres where sulphur oxides are the predominating corrosive influence. In atmospheric exposure tests aluminum coatings 3 to 4 mils thick were found to give good protection for several years, probably due to their tendency to be self-sealing. The corrosion product seals up the pores in the coating and provides a protective skin on the coating metal. Commercial purity aluminum (99.5%) gives better protection than super-purity (99.9%).

Sprayed aluminum is also used for protection of high-strength aluminum alloys of the copper-bearing type, but it is not suitable for light alloys rich in magnesium.

In sea water also sprayed aluminum protects steel by its self-sealing action. Thin coatings (3 mils) were found to be in perfect condition after 16 months exposure. Sprayed aluminum is usually preferred to sprayed zinc in natural waters of low pH value.

It was found that sprayed aluminum coatings, immersed in water saturated with carbon dioxide, corroded during the first few days and then remained unchanged over a period of six months. Coatings 5 mils thick were rust-stained while coatings 10 mils thick were not, because, in the latter, the pores did not penetrate to the base metal. Staining of the thinner coatings did not seem to impair their life.

Zinc – In a high-humidity atmosphere polluted by sulphur compounds, the protection given by sprayed zinc coatings is not as good as that given by aluminum due to the formation of deliquescent and water-soluble zinc salts and to the higher solubility of the corrosion product. The life of zinc coatings in a particular atmosphere is largely

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...and one for the pot!

Witches of old brewed heroic broths to encourage visions, prognostications, spells, and spasms. Even unrequited love yielded to these near-lethal potions. Add the tail of a cat, the ear of a rabbit, sixteen varieties of tree roots, and a few "trigger" ingredients, known only to the witches guild... and stand back!

Folklore ignores the witches' maintenance problems, but such overwhelming corrosives must have liquidated many a cauldron inventory. After all, the witches had no titanium.

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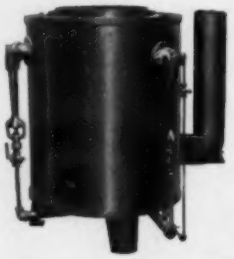

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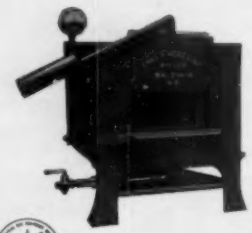

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Sprayed zinc is widely used in atmospheres where the sulphur pollution is low. In rural and marine atmospheres, coatings about 3 mils thick have given good protection to steel for more than 12 years; however, in an industrial atmosphere the life of a similar coating was 3½ to 4 years. In some instances it may be desirable to use zinc even in a heavily polluted industrial atmosphere because of the greater degree of cathodic protection provided. Sprayed zinc was found to be much superior to sprayed aluminum in the atmosphere of a large chemical plant where nitric and sulphuric acids, ammonia and ammonium sulphate are produced.

Sprayed zinc should not be used in hot soft waters or hot condensate because of the possibility of the coating becoming cathodic to the base metal. However, in hard waters zinc gives better service than aluminum.

Sprayed zinc provides excellent protection to iron and steel in contact with sea water. Specifications call for a coating thickness of 6 to 8 mils. It appears that a zinc coating is best left unpainted in sea water in order that general corrosion rather than local pitting may take place.

A. COUTURE

The Tempering of Plain Carbon Steels

Digest of "The Tempering of Plain Carbon Steels", by E. D. Hyam and J. Nutting, *Journal* of the Iron and Steel Institute, Vol. 184, October 1956, p. 148-165.

THE MECHANICAL PROPERTIES and microstructure of quenched carbon steels change when the steel is tempered. These changes take place in four stages:

1. Precipitation of close-packed ϵ-carbide.
2. Decomposition of the retained austenite.
3. Formation of thin platelets of cementite.
4. Formation of spheroids, from the thin platelets, which gradually

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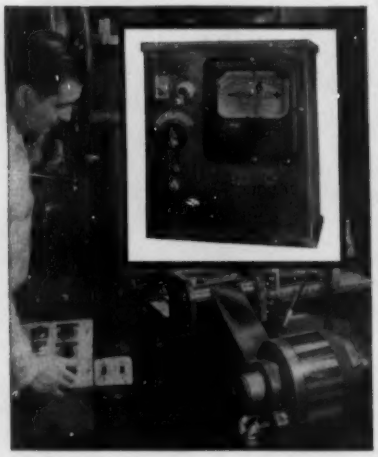

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Tempering . . .

increase in size and decrease in number.

A large amount of data is available relative to the first three stages but very little about the fourth.

Four carbon steels, two of them basic openhearth steels, containing 0.125 and 0.34% carbon respectively, and two acid openhearth steels containing 0.79 and 0.985% carbon respectively, were selected for the investigation. The specimens were austenitized at 120° F. above their A_3 temperature, quenched in iced brine, and refrigerated in liquid air to reduce the amount of retained austenite to a minimum. This was followed by tempering at each of the following temperatures: 930, 1110, 1200 and 1290° F. The tempering times were ½, 1, 2, 5, 10, 20, 50, and 100 hr.

Specimens for metallographic examination were polished and etched in 0.5% Nital. Formvar replicas were dry-stripped from them and examined in the electron microscope. Two electron micrographs were made at 2500 and 10,000 × magnification. These photographs were used for determination of the carbide particle size and the distribution of the ferrite grain size. The ferrite grain size for each sample was estimated by averaging the long and short axes of 30 grains randomly selected. Hardness surveys were made after metallographic examination.

The tempering treatments yielded microstructures consisting of spheroidal particles of iron carbide dispersed in a ferrite matrix. The microstructures varied with respect to the degree of dispersion and the amount of carbide present.

Micrographs of samples tempered for a short time at low temperatures revealed carbide precipitation along the pre-existing austenite grain boundaries. Lenticular areas adjacent to the austenite boundary contained smaller and more uniform carbides than the other areas. With further tempering both these phenomena disappeared.

The hardness of the steels was checked before and after tempering.

From these values the activation energy of the softening process was calculated to be approximately 60 kg-cal. per g-mol.

The test results were carefully

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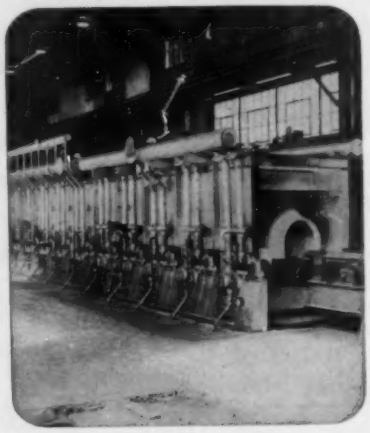

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Tempering . . .

studied and compared to those of other investigators. The studies indicated that the previously established relationships did not account satisfactorily for the changes produced by tempering. As a result of the studies a new hypothesis, which appears to offer a more plausible explanation of the tempering mechanism was suggested.

The hypothesis states that the hardness of tempered steel is inversely proportional to the ferrite grain size, the softer the steel the larger the grain. The carbide particles at ferrite grain boundaries limit their growth, therefore the ferrite grains can grow only as the carbide particles grow and the steel becomes softer.

It was concluded that:

1. If samples of a given carbon steel are subjected to various isothermal tempering treatments, which result in the same hardness, they will have the same microstructure.

2. If steels of increasing carbon content are tempered to the same hardness, the mean particle diameter, surface, volume, and surface-to-surface spacing will increase and the total particles per unit volume and total particle surface area will decrease.

3. The size frequency distribution of the carbide particles varies with the carbon content of steels tempered to the same hardness.

4. The activation energy of the tempering process corresponds with that of the self-diffusion of α-iron.

5. A linear relationship exists between the Vickers hardness and the reciprocal of the square root of the calculated ferrite grain diameter.

6. In the fourth stage of tempering the ferrite grains and carbide particles grow simultaneously.

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Embrittling Action of Salt Bath

Digest of "Embrittlement of Ship Steel in a Nitrate Salt Bath", by D. C. Garibotti, C. A. Beiser and E. B. Evans, *Welding Journal*, Vol. 35, August 1956, p. 383s-388s.

IN THE FIRST STAGES of an investigation on the effect of subcritical heat treatment on the transition temperature of a 1025 semikilled ship steel (Ship Structure Committee "Project Steel C"), both air and a nitrate salt bath were used as heating media. It was observed that test specimens heated in the salt had the same or higher transition temperatures and hardness as specimens comparably heated in air. This embrittlement was superimposed on any embrittlement arising from the normal quench-aging behavior of the steel. The effect of the nitrate salt bath was noticeable after 4 hr. immersion at 1100° F.

A metallographic study was undertaken. The only difference between air cooled and water quenched microstructures after heat treatment in salt is the more mottled appearance

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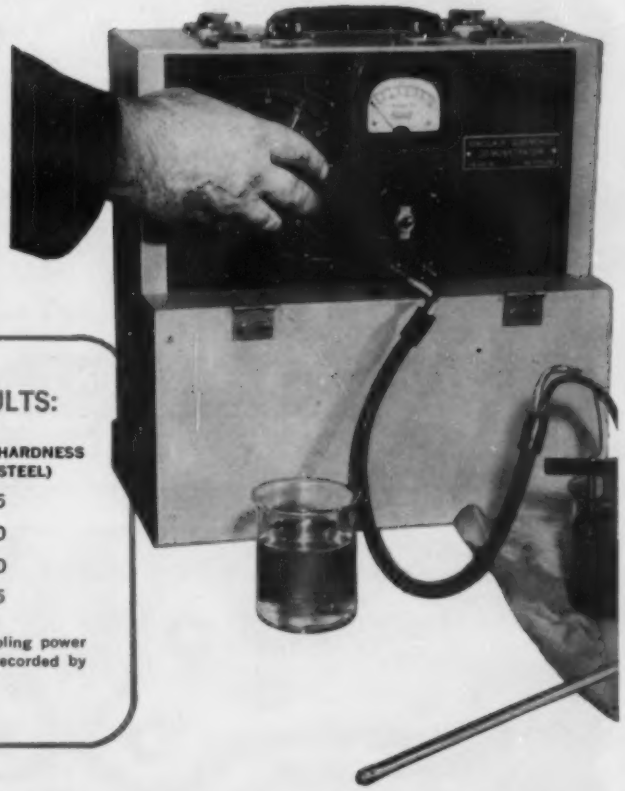

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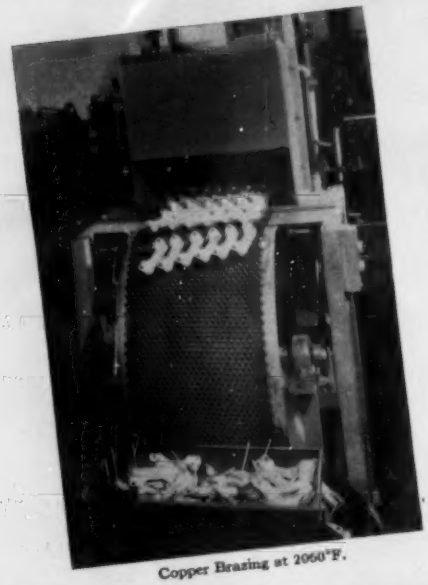

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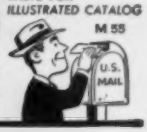

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Salt Baths . . .

of the ferrite after water quenching. However, with a critical cooling rate (furnace cool) short platelets of a precipitate, arranged in a Widmanstatten pattern, appear in the ferrite. Electron micrographs of this structure reveal more detail; they show that near the surface of the furnace cooled Charpy bar a fine precipitate is distributed throughout the grains in heavier concentration than in the center of the bar. In addition, a long needle-like phase is fringed with a fine precipitate. The two different forms of the platelets (or needles) suggest a concentration gradient from the edge of a specimen to the center, and their form and distribution suggest nitride needles. This structure is not evident with furnace cooled specimens after the same heat treatment in air, although this steel has the highest original nitrogen content of the project steels.

To confirm that the specimens heated in salt were enriched with nitrogen, nitrogen analyses were made by both the wet method for combined nitrogen and the vacuum-fusion method for total nitrogen. Both methods of analysis showed that subcritical treatment in salt resulted in a high nitrogen pickup, whereas comparable treatments in air did not. The nitrogen phases were then identified by X-ray diffraction methods to be Fe_4N (short platelets) and Fe_3N (long platelets).

The increase in nitrogen after treatment in the nitrate salt is considered to arise from a scaling reaction of the specimens, allowing the nitrogen to diffuse into the metal. To show that the increased nitrogen content is not due to preferential oxidation of the iron, a few impact blanks were vacuum treated (2200° F. for two days) to remove all nitrogen. Subsequent heat treatment (1100° F. for 112 hr.) in nitrate salt and air, employing a furnace cool, showed the presence of nitride in the salt-heated specimens only.

Two factors are held responsible for the embrittlement action of the salt bath treatment. The first is an alloying effect which manifests itself by an increase in hardness and loss of ductility with increasing nitrogen content.

The second effect is a combined

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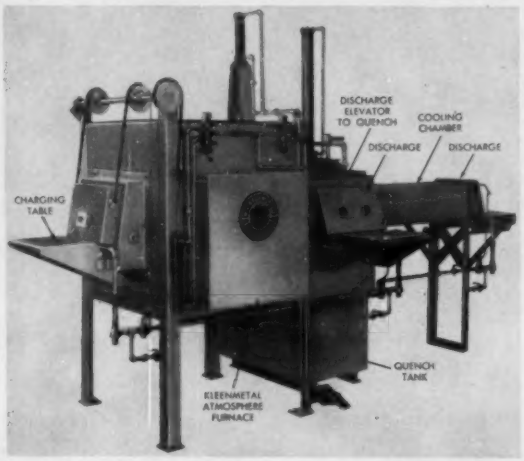

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Salt Baths . . .

solution and aging phenomenon, commonly referred to as "quench-aging". The aging effect was indicated by the fact that the hardness of as-quenched specimens increased with time at room temperature. Since both carbon and nitrogen are believed to embrittle steel by the quench-aging mechanism, the contribution of each to the over-all embrittlement cannot be readily separated.

F. FORSCHER

New Materials for Ball Bearings

Digest of "Special Materials for Unusual Ball Bearing Applications", by William Blinder, *General Motors Engineering Journal*, Vol. 4, January-February-March 1957, p. 42-46.

INCREASINGLY SEVERE conditions of speed, load, temperature and corrosive atmospheres, as for example in jet engine and nuclear energy applications, have placed new demands on ball bearing materials. Inner and outer rings, balls and separators are coming under careful scrutiny to meet these new developments, and new materials, metallic and nonmetallic, are being reviewed constantly.

Basically the ball bearing is a means of carrying a heavy load at high speeds with low friction and minimum lubrication. Even under light loads, Hertz contact stresses between balls and races generally exceed 100,000 psi. and often are as high as 500,000 psi. For most applications, the required speeds, loads and temperatures (up to 450° F.) involve no particular problems and satisfactory lubrication may be obtained by oil jet, splash or mist systems, grease, or in some instances by an initial light oil coating which lasts for the life of the unit. However, these bearings are sensitive to fits and alignment, dirt and other contaminants. Furthermore, the cleanliness of the steel selected, or its freedom from nonmetallic inclusions, is most important since oxide, silicate, aluminate and sulphide inclusions are known to be major offenders in causing bearing fatigue failure.

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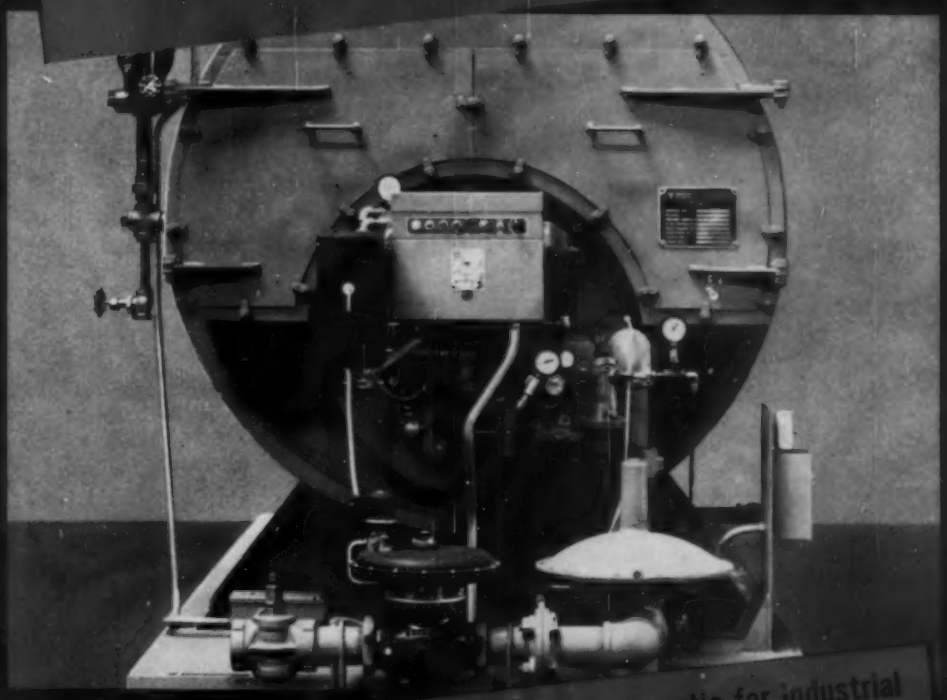

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Ball Bearings . . .

bearings are of the high-carbon high-chromium variety – A.I.S.I. 52100 for rings, and A.I.S.I. modified 51100 for balls. These electric furnace steels contain about 1% chromium and 1% carbon and are used in the fully hardened condition, tempered to Rockwell C-62 to 64. Other analyses include A.I.S.I. 440 C stainless steel for mildly corrosive conditions, and A.I.S.I. 5120, a high-quality case hardening steel, for bearings where a ductile core is necessary for toughness and high impact strength.

Separator or cage materials for usual operating environments are generally A.I.S.I. 1010 or Type 430 stainless steel, of stamped-ball controlled design for low or normal speed conditions, and either fabric-base phenolic or bronze ring separators for higher speeds.

Principal properties desirable in ball and ring materials are high endurance under fatigue loading, high impact strength, hardness high enough at the operating temperature to carry the applied loads without permanent deformation, good gall and wear resistance, good corrosion resistance, high dimensional stability, uniformity and freedom from segregation, and reasonable cost of material and processing.

Standard 52100 and 51100 steel bearings stabilized for elevated-temperature operation have been used successfully at temperatures up to and, occasionally, above 450° F. However, at temperatures above 300° F. structural and dimensional changes occur due to transformation of martensite, the rate of change increasing with temperature.

Materials with the greatest promise for temperatures up to 900 to 1000° F. are the high speed tool-steels. They have good hot hardness, dimensional stability and high-temperature strength because of their tungsten, cobalt, molybdenum and vanadium contents. A basic disadvantage is that, as commercially made, they contain excessive non-metallic inclusions. Progress has been made in eliminating this defect by vacuum melting.

Nonmagnetic bearing materials are desirable for applications where the magnetic properties of conventional materials may disturb equipment operation or where an accidentally magnetized bearing may radiate a signal which would interfere with nearby radio operation.

Corrosion resistant materials are required for operation in pressurized water at temperatures up to 600° F., in air or inert gas at temperatures up to 1600° F., and in corrosive gases at various temperatures. Lubrication other than in the operating medium generally is not possible in these environments. Non-galling and wear resistance are important under these conditions. Cobalt, chromium-base, nickel-base, and copper-base alloys all have been tried, often with good results, at other times marginally. Laboratory tests have been run on materials such as sintered tungsten carbide, sintered chromium carbide, glass, sapphire, graphite and cermets. Inherent brittleness is a common defect with these materials.

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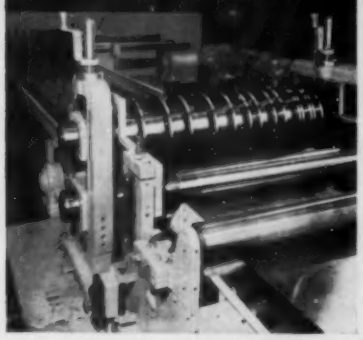

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Effect of Service Temperature on Refractory Materials

Digest of "Some Changes in the Properties of Refractories at High Temperatures", by C. Bodsworth, *Iron and Steel,* Vol. 29, June 1956, p. 297-321.

THIS PAPER is a review of existing knowledge, and does not contain new experimental data.

Properties of refractories quoted by manufacturers for products subsequent to firing are not necessarily related to the properties of the same materials after extended exposure to service conditions. It is well known that marked changes in properties often occur during use. This does not mean that test data on unused samples are irrelevant; it does mean, however, that such data should be correlated with an understanding of the changes that may occur in the material during extended exposure to conditions of high temperatures, liquid and gaseous fluxes, and cyclic variations. It is the purpose of this paper to review certain underlying principles that directly influence the performance of refractories in service, and to correlate these principles with observed behavior.

For example, in high-silica refractories the individual atoms constituting the lattice of the crystals may reorient themselves with respect to their neighboring atoms to form quartz, tridymite, or crystobalite, depending on the temperature and time of exposure. During service at elevated temperatures such changes will trend toward the equilibrium structures. Moreover, each of these forms of silica is capable of undergoing still further modification of structure on heating and cooling. Such structural changes involve quite marked volume changes. Thus the thermal expansion from 0 to 1830° F. of tridymite is roughly 0.3%, whereas crystobalite expands by approximately 1.0% in the same temperature range. This large expansion differential, combined with the low modulus of elasticity of the silica network, will increase the spalling tendency and may well lead to cracking between the tridymite and the crystobalite zones.

Another factor influencing the refractory behavior, particularly in the

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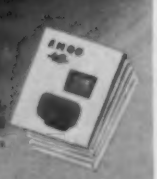

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Refractories . . .

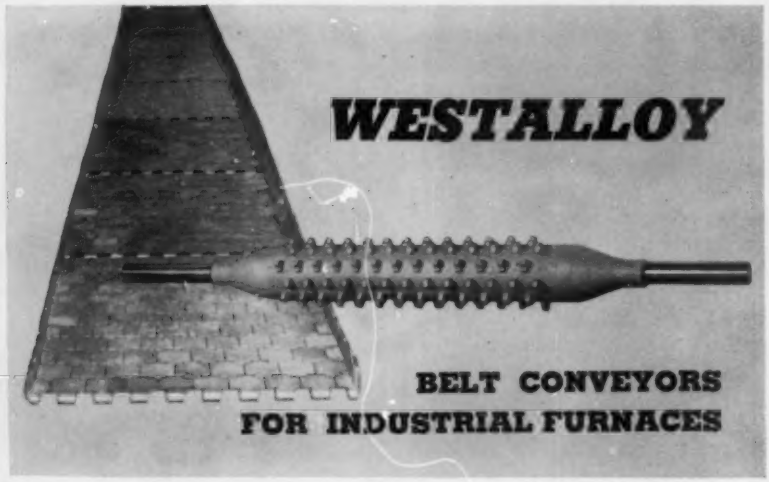
alumino-silicate class of refractories, is the change in viscosity of the matrix phase during firing and during extended service at elevated temperatures. The occurrence of differences in viscosity of the liquid has a marked effect on diffusion processes. Thus, an important source of difficulty directly related to viscosity changes is contamination in service. When certain types of contamination occur, very marked changes in the mechanical and the physical properties often result.

For example, when a liquid forms on the surface of a refractory brick, capillary forces will tend to draw it through channels connecting the pores back into the region behind the hot face. Here it has an opportunity to react with and eventually saturate the refractory constituent. This type of contamination is directly related to the viscosity of the liquid phase. Consequently, if the reaction products located between the refractory grains become solid due to a change in viscosity, they will substantially modify the overall properties of the refractory. In this manner the thermal shock resistance, or the spalling index, may be adversely affected due to differences between the coefficient of thermal expansion of the refractory material and that of the contaminating reaction products.

Two further properties of refractory constituents are discussed, both of which result in an over-all expansion of the refractory material, and consequently have important influences on performance. These properties are bloating due to gas evolution, and expansion caused by inherent chemical changes producing new phases. Hence, the avoidance of potential sources of gas evolution or the occurrence of elements that would produce volume change reactions must be minimized in order to avoid these difficulties.

In this review the author has touched upon several of the more important factors controlling the behavior of refractories at high temperatures. He has indicated that a number of other factors must also be considered before a complete picture can be formulated, and that much research will be required before one can confidently predict the behavior of a specific refractory under any given set of conditions.

W. W. AUSTIN



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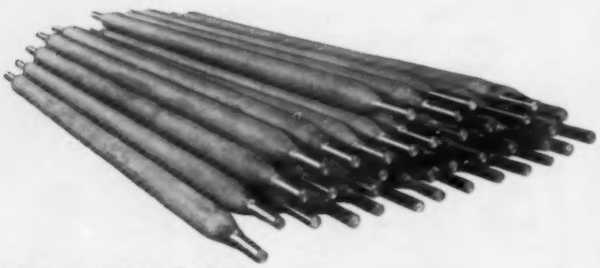

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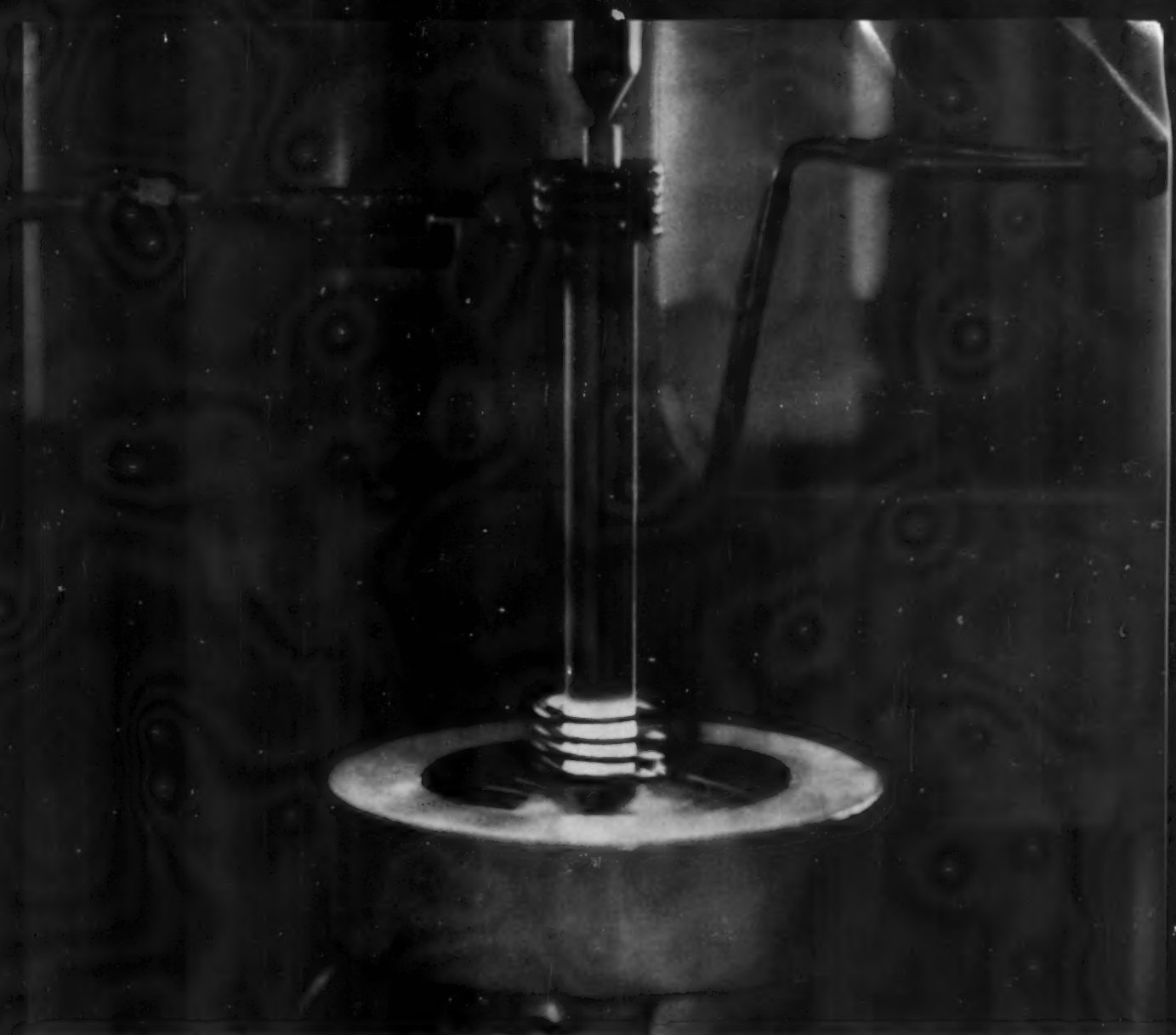
Ultrasonic Welding

Digest of "Ultrasonic Welding", by J. Byron Jones and James J. Powers, Jr., *Welding Journal*, Vol. 35, August 1956, p. 761-766.

ULTRASONIC WELDING is a method of bonding similar or dissimilar metals by the introduction of ultrasonic energy into the metals at the area to be joined. The pieces to be joined are clamped at low pressure between two welding members or sonotrodes, specifically designed for each specific welding application and the vibratory energy is introduced for a brief interval, generally 1 to 3 sec. Solid-state metallurgical bonds are produced with insignifi-



Ketos shaft being induction hardened to Rockwell 55-56, while ends remain soft for final machining. Photographed at Control Instrument Co., Inc., Brooklyn, N. Y.

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Ketos is a low priced alloy tool steel that can be hardened from low temperatures with practically no volume change. It has deep hardening qualities, and a fine grained structure, that make it desirable for many production parts.

That's why nondeforming Ketos is well suited not only for most tool steel applications such as gauges, dies, and taps but also for close-tolerance, wear-resistant parts like the actuator bar shown in the induction heating unit above. The thin contact edges of this particular part withstood a "life test" of over 4-million high speed blows. No other steel tested lasted more than 1-million cycles before it chipped and failed.

If Ketos sounds like the steel you should be using, call your nearby Crucible warehouse. Stocks of Ketos and dozens of other special tool steels are large, delivery fast. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

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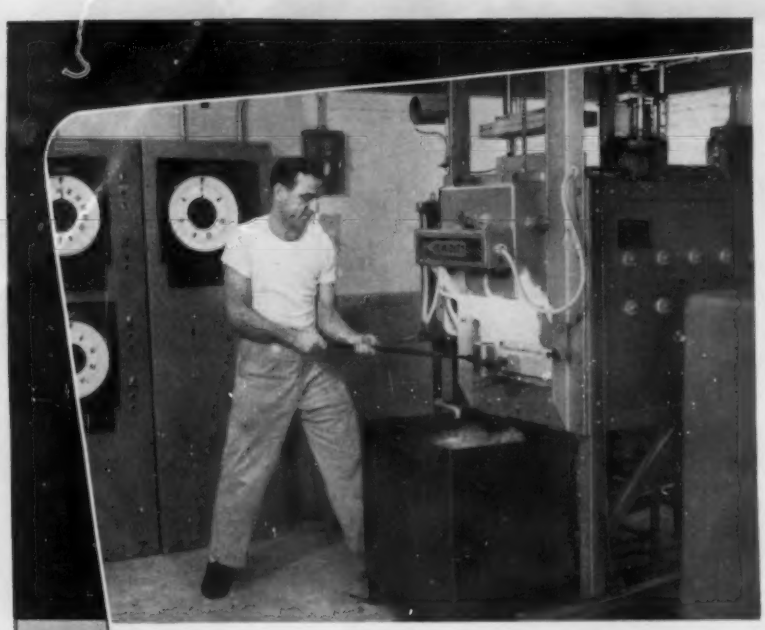

Faster solution-heat-treating with a Hevi-Duty

CONVECTION BOX FURNACE

The Beryllium Corporation uses this Hevi-Duty Multi-Range Convection Box Furnace in their process control laboratory for solution-heat-treating "Berylco", Beryllium Copper alloys. The laboratory director reports outstanding results and economy due to the following advantages:

1. Rapid heating to solution temperatures (1450 or 1700°F depending on the alloy being treated) is made possible by a motor driven fan that circulates the hot gases through the densest of loads, and by,
2. Direct, even heat radiation to all surfaces of the load by Hevi-Duty Return Bend heating elements on all six sides of the furnace chamber.
3. Control of temperature within ±5°, throughout the chamber.
4. Elimination of oxidation by use of a protective atmosphere.
5. Freedom of both hands for rapid charging, discharging and quenching by a foot treadle operated door.

For further information about Hevi-Duty Convection furnaces, write for Bulletin 341R.

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Ultrasonic Welding . . .

cant external deformation of the pieces.

During the past four years, development work has resulted in good bond strength in ultrasonic sheet-to-sheet welding of a number of metals. This type of welding achieves roughly the same order of strength – at least with aluminum – as does the older technique of high-pressure welding. However, ultrasonic welding differs from ordinary pressure welding in that bonding is accomplished (*a*) without meticulous attention to surface preparation, (*b*) with little deformation (less than 5%), and (*c*) with lower applied static compressive loads.

Starting with foil thicknesses of aluminum, the process is now capable of single weld strengths in the order of hundreds of pounds in a variety of metals. Flat sheets and long tube spirals may be welded.

A mechanical device has been developed which delivers a combination of shear and compression vibration to the plane of the weldment. Little energy is lost to the mounting system so that the energy delivered is concentrated in the weld zone. Applied power is in the range of 100 to 1800 watts. The static force applied in welding ranges between 10 and 350 lb. Low static forces go with small welds, thin materials, soft materials and low power whereas greater loads go with the reverse of these factors. The frequency range investigated has covered 4 to 40 kc. per sec. with the thinner materials responding to higher frequencies and the thicker materials to lower frequencies.

Welding results partly from deformation at the interface which is internally of the order of 80% for foil thicknesses and lower with sheet thicknesses. In addition, dynamic internal stresses cause internal plastic flow at the interface, generating heat and resulting in a temperature rise. Theoretical considerations indicate a possible temperature of about 600° F. Temperature measurements in welding aluminum indicate temperatures of about 400° F., whereas with aluminum-to-Monel sheet welds 1000° F. is attained. In no instance does temperature approach the melting point of aluminum, and microscopic ex-

amination reveals no evidence of fusion. Clearly this is solid-state welding.

No metal has yet been encountered which could not be ultrasonically welded, although all possible metal combinations have not been tried. The work to date has revealed the following feasible uses of ultrasonic welding:

1. Materials of foil thickness can be metallurgically joined.
2. Materials of foil thickness can be joined to heavy rod, plate or tubes.
3. Small buttons of metal can be joined to heavier sheet, plate or ribbon.
4. Sintered aluminum powder products can be welded.
5. Copper up to 0.040 in. can be welded.
6. Dissimilar metals can be joined.
7. Air-tight containers can be made by welding impact extrusions and squeeze tubes.

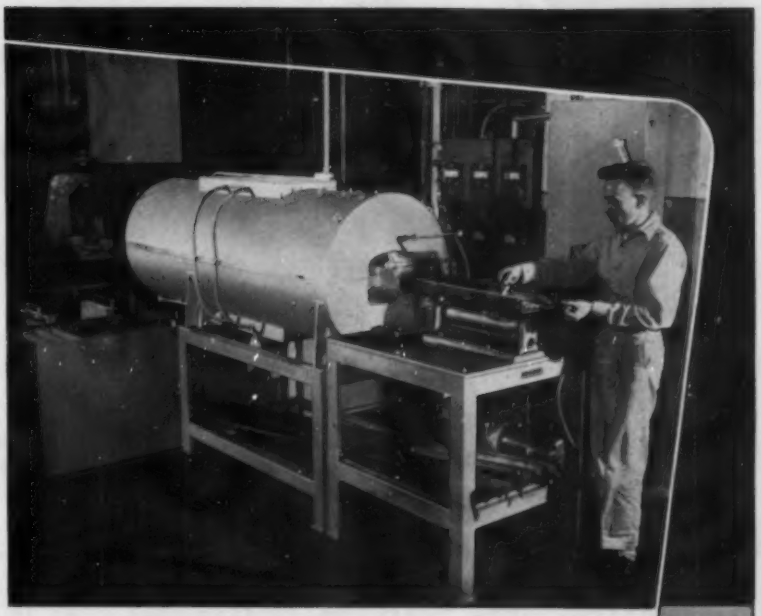
H. J. NICHOLS

Rapid Heating of Steel Ingots for Hot Working

Digest of "Increased Heating Rates for Steel Ingots", by P. M. Cook and J. D. Stringer, *Journal*, Iron and Steel Institute, Vol. 184, November 1956, p. 309-315.

THE HEATING of steel ingots and billets for hot working is generally done very slowly, or at the rate of 20 to 35 min. per in. diameter as advocated in textbooks (by Trinks for instance), to avoid internal cracks from thermal stress. But this may be a waste of time and fuel, and may also cause unnecessary scale loss. A paper by E. Terlecki appeared in Poland in 1952 showing how ingots as large as 35 in. diameter, of low-alloy and low-carbon steels, were worked without trouble after heating for about 3½ hr. in a furnace at 2550° F. They were withdrawn for working when the surface reached 2370° F. More brittle steels were first preheated at about 1300° F. before heating in a similar way to the working temperature. Two years later in England F. O. Hess reported that 19 × 23-in. mild steel ingots could be rolled safely after heating only 2 hr. with Selas gas burners.

A report of later experiments to



Quality carbonitriding of small parts with a Hevi-Duty

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Allen-Bradley uses this Hevi-Duty Furnace for carbonitriding stampings, springs, cams, and rollers. Norman Hetzel, heat-treat foreman, says, "This Hevi-Duty Shaker Hearth Furnace represents a modern technique in heat-treating that is consistent with Allen-Bradley's policy of using the best new equipment in the manufacture of quality products."

Improved quality of parts results from the combination of superior design features, a proper atmosphere in the furnace chamber and a direct oil quench.

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Heating of Ingots . . .

check these results has now been published. Several 8 to 10-in. square ingots of 0.6% C steel, and 2.5% Ni-Cr-Mo steel were drilled for inserting thermocouples and charged cold into a furnace at about 2500° F. according to Terlecki's method. The ingot surfaces quickly became about 540° F. hotter than the centers, but about 40 to 60 min. later, when the ingots were withdrawn at a surface temperature of about 2280° F. and air cooled, the centers were up to about 2100° F. A few minutes after withdrawal, the centers were hotter than the surfaces, the same as in conventionally heated and well-soaked ingots. None of the rapidly heated ingots cracked, and forging tests showed no excess power required, and no flaws in the billets.

High speed steel ingots (18% W, 4% Cr, 1% V) 4 and 6 in. square were tested first in a preheating furnace. The 4-in. ingots, cold and as-cast, could be charged safely into a preheating furnace at 1830° F., and the 6-in. at 1620° F., but if the furnaces were much hotter the ingots cracked. After only about 5 min. in the preheating furnace the 4-in. ingots reached about 570° F., and could then be charged safely into a furnace at 2460° F. Heating 22 min. in this furnace brought them to the forging temperature of 2190° F. without cracks and with the center temperature very close to that of the surface. The 6-in. high speed ingots required 30 min. in the preheater at 1620° F. to reach 930° F., which was safe for charging them into the 2460° F. furnace for heating in less than an hour to the forging temperature. No structural damage was produced. A safe general practice would be to preheat for 30 min. in a furnace at 1470° F., and then transfer to a furnace at 2190 to 2250° F. for at least 30 min. before forging.

No more difference in forging power was found with these ingots than is usual with ingots heated for 24 hr. Although the structure had been broken up to some extent after forging to 2 in. square in the rapidly heated material, the characteristics of the as-cast structure and the carbide network persist to a greater degree than in the slowly heated material, but after further reduction to ⅝ in., the microstructures were almost identical. The rapidly heated steel showed much less decarburization at the bar surface.

The rapid heating method was then tried on 4-in. square 18-4-1 high speed steel ingots in regular mill production. Six annealed ingots in one plant, and 12 as-cast in another, were heated in accordance with the 1-hr. schedule described above, using two furnaces, and all forged very well without cracking. Tool bits ½ and ⅝ in. square were made from six other ingots heated in this manner, and their hardness and surface appearance were compared to similar bits made from six ingots of the same steel that had been heated slowly. The proportion of bits rejected was higher for the slowly heated steel than for the 1-hr. heating, and a few comparative cutting tests of drills also showed no poorer results from rapid heating.

In other steel plants where two-stage heating was inconvenient, more rapid heating of high-alloy steels in a single furnace has also been found safe and economical; decarburization, scale loss, and fuel consumption all were reduced. At one plant 6-in. square ingots were charged at 1100° F. and raised to 2150° F. for forging in 6 hr. instead of taking 8 hr. for heating and then holding an additional 7 hr. before forging, as had been done pre-

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Heating of Ingots . . .

viously. At another plant a continuous furnace for ingots up to 12 in. square was modified by baffles and burner changes so that the ingots heated to 2245° F. in 8 hr. were above 1470° F. for only 1.5 hr. instead of 5 hr. The forgeability of various alloy steels was as good as before, and complaints about decarburization ceased.

Although a marked reduction in the usual heating time of high-alloy toolsteel ingots before forging has thus been found entirely safe and advantageous in commercial practice, similar trials of rapid heating of very large low-carbon and low-alloy steel ingots were not included in this work. Laboratory tests of 10-in. ingots of the latter types of steel, however, indicated that rapid heating according to Terlecki's principle is practical and that industrial trials of the method on larger ingots should be well worth while.

GEORGE F. COMSTOCK

Cavitation Erosion

Digest of "A Study of Cavitation Erosion", by Bernard Trock, Society of Automotive Engineers, Preprint No. 758, 1956, 11 p.

ONE OF THE most prevalent types of failure in present-day high-speed diesel engines is cavitation erosion, which is a peculiar form of corrosion occurring on the water side of cylinder liners. It is also found on hydraulic turbines, centrifugal pumps and high-speed ship propellers.

Cavitation may be defined as the formation of voids within a body of moving liquid or around a body moving in liquid when the particles of liquid fail to adhere to the boundaries of the passageway. In a similar manner cavitation erosion may be defined as the damage resulting to the surfaces on which these voids form.

As a result of numerous investigations, several theories have been postulated to explain the mechanism of cavitation erosion. The principal ones are:

1. Cavitation erosion is the result of a liquid penetrating the pores of a material under pressure and sub-

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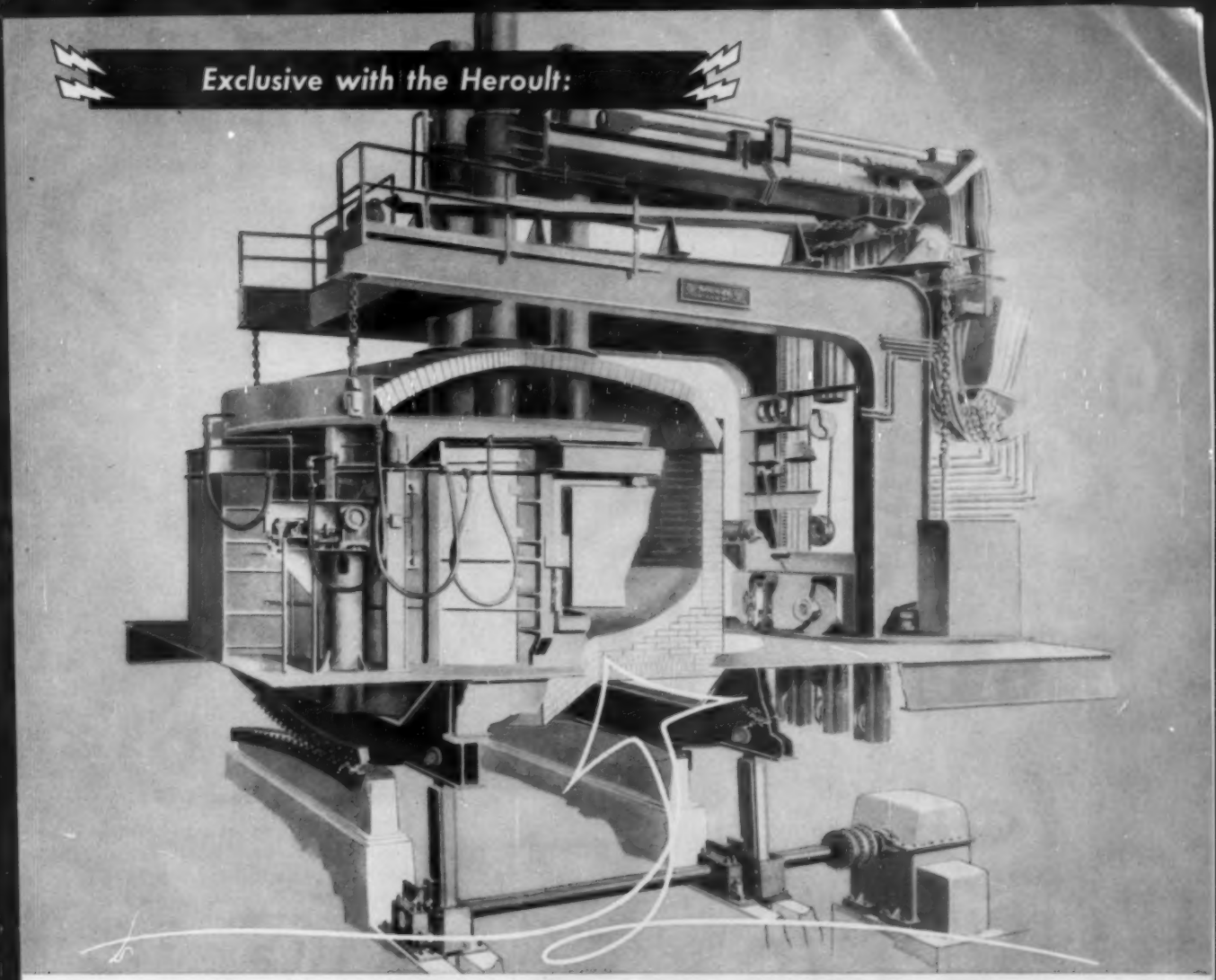

Flat Bottom Shell

THE EXCLUSIVE Flat Bottom Shell construction of Heroult's NEW electric furnace facilitates installation of the hearth lining, resulting in lower refractory costs and shorter down time for relining.

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Flat Bottoms also permit the use of thicker refractories at the sides of the hearth, resulting in more uniform bath temperatures, essential for the production of quality steels.

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UNITED STATES STEEL

sequently escaping, carrying some of the material with it.

2. Cavitation erosion is the mechanical disintegration of surface layers under repeated highly localized pressure pulses. These pulses are caused by the sudden collapse of cavities in contact with or close to the surface.

3. Cavitation erosion is caused by superheated steam at extremely high pressure. This steam is the gas or vapor in the cavitation bubbles.

Numerous experiments which tend to substantiate the above theories have been performed; however, each theory contains at least one flaw which cannot be reconciled with the experimental data.

Three experimental test methods have been used to determine the relative resistance of materials to cavitation erosion, the Venturi method, the rotating disk method, and the vibratory method. They all place materials in the same order of relative resistance although the extent of the pitting varies. In each case the criterion for determining the relative resistance is the weight loss of the test specimen.

Diesel Engine Cylinders – Cavitation erosion was first noted in tractor engines of a certain make and model. Other models from the same manufacturer, operating under identical conditions, remained free from attack. The attack could be reproduced in the laboratory using single-cylinder test engines, but only with the type of cylinder which pitted in the field. Subsequently, this type of pitting was discovered in the diesel engines of ocean liners, railroad trains, and trucks.

Hydraulic Turbines – Cavitation erosion was first noticed in 1890 when the Francis turbine runners of the Jaice hydro-electric works in Bosnia failed after only a few weeks' operation. The runners were so badly eroded by cavitation that they had to be replaced. Subsequently, there have been numerous reports of other failures.

Centrifugal Pumps – Cavitation erosion is a direct result of the high impeller speeds in use today. Numerous investigations have resulted in improving the pumps to a point where they can safely operate at much higher speeds, but complete elimination of the erosive effects is yet to be accomplished on an economical basis.

Accelerated Cavitation Tests

The Studebaker-Packard Corp. encountered the problem of cavitation during the development of a lightweight six-cylinder high-speed diesel engine. In an effort to combat this condition they investigated the effects of many factors such as liner surface coatings, increase in water flow rates, and introduction of air bubbles. Although all these factors affected the rate of pitting, interest was focused on surface coatings because they could be tested rapidly and inexpensively by the vibratory method.

A number of test buttons made of Nitralloy G were plated with various thicknesses of nickel, chromium and tungsten carbide and tested. Two buttons plated with 0.010 in. of self-regulating chromium over 0.003 and 0.008 in. of nickel plate possessed the greatest resistance to pitting, although the plating on one of them was penetrated at one point. This penetration occurred at a spot where previous examination had revealed a pit. Since the plating was penetrated at the pit only it emphasized the need for an absolutely flawless surface in order to obtain the maximum resistance to pitting.

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2. Screw Feed—Automatic or Hand Driven.
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4. Simple Positive Coolant System.
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Better Machines-Better Blades

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Warranty: 16 oz. of First Quality in every pound!

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FOR HOT WORK

Produced by Vanadium-Alloys Steel Company to *first quality* metallurgical and performance standards, these die steels match every hot work need in the metal-forming industries. They are the specialized products of tool steel specialists, made in a plant devoted exclusively to fine tool steels. Let our district sales engineers aid you in selection and application—their trained services are yours without obligation of any kind.

Hotform — The most widely used of all hot work die steels. 5% chromium—tops in strength and toughness, plus resistance to heat checking. Use for die casting, extrusion and hot forging dies, backer blocks, mandrels, etc.

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SC Special — 14% Tungsten Die Steel with increased carbon for better wearing properties. Particularly adapted for extrusion punches, piercers, and forming dies.

Marvel — 10% Tungsten Hot Work Die Steel for tools requiring better resistance to high temperatures. Excellent for punches, nut piercers and dies, and brass forging dies.

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Forge-Die — 14% Tungsten Hot Work Steel, having high resistance to softening at elevated temperatures. Recommended for piercers, punches, and hot forming dies.

WW Hotwork — High Alloy Steel developed for maximum wear resistance at elevated temperatures. Used for copper and brass extruding dies, brass die casting dies, piercers for copper tubing, and nozzles on zinc die casting machines.

WCC — New, very deep hardening tungsten, chromium, cobalt and vanadium steel—outperforming 9.50 tungsten types. High resistance to wear and thermal fatigue. Use for hot extrusion dies, permanent molds for brass casting, forging die inserts, hot-press dies.

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Latrobe, Pennsylvania

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Industrial Uses of Titanium

Digest of "Industrial Potential of Titanium," by R. L. Carmichael, *Battelle Technical Review*, Vol. 5, December 1956, p. 9-13.

THE U.S. GOVERNMENT consumed 95% or more of the 7500 tons of titanium produced in 1955, but has recently permitted the application of 10% of all titanium mill products to nondefense uses. The chief advantages of titanium for industrial applications are its high resistance to abrasion and corrosion in most oxidizing environments, as well as its high strength-to-weight ratio, but it suffers from high cost, susceptibility to galling, and difficulties in casting, welding and fabrication.

Its chief nonmilitary field of application at the present time is in commercial aircraft, for engine cowlings and firewalls. Titanium is also becoming an important material in the chemical and process industries where corrosion resistance and absence of contamination of products in contact with it are important. Because of titanium's excellent resistance to salt-water corrosion, many people in the industry are of the opinion that marine applications eventually may become one of the more substantial uses of the metal.

Successful applications in the chemical field are reported in the construction of the following items: an impeller operating in hot acid organic chloride solutions with free chlorine; filter press parts exposed to calcium hypochlorite; a condenser handling hot 60% nitric acid; a jet diffuser for steam in dilute hydrochloric acid; valve trim for corrosive fluids; an agitator cover exposed to chromic acid crystals in hot sulphuric acid; and an autoclave liner holding hot 28% sulphuric acid.

The high cost of titanium has limited its ability to replace other metals economically. Since 1954 the price of sponge has fallen from $5 per lb. to below $3, but rods and bars are still more than $7.50 per lb. and sheet or strip more than $12 per lb., which means that per square foot the cost is ten times as great as that of stainless steel. Since the greater part of the cost of most finished equipment lies in fabrication, the cost of finished titanium equipment in some instances may be only two or three times greater than that for stainless steel. Titanium's longer life in some applications can sometimes justify such an increase.

On the other hand secondary fabrication of titanium is generally found to be more costly. A good deal of the difficulty is due to lack of experience on the part of the secondary fabricators. Those shops that have had experience in working stainless steel have not encountered as many difficulties as have other shops. Education and experience will do much to solve this problem, as it did when stainless steel was first introduced to industry.

Economic factors are expected to improve, and in five years if titanium mill products are 50% lower in price, as some producers estimate, titanium should find many more applications in the chemical and process industries.

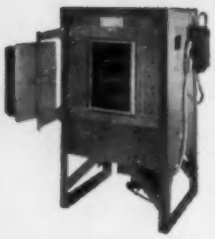
GEORGE F. COMSTOCK

Cooley ELECTRIC HEAT TREATING FURNACES
35 MODELS

New GA batch type controlled atmosphere furnace designed for tool rooms and small production. 2 models now ready—others to follow.

INDUSTRIAL BOX FURNACES WITH AND WITHOUT Controlled Atmosphere

High Speed and Recirculating Electric Furnaces Electric Ovens



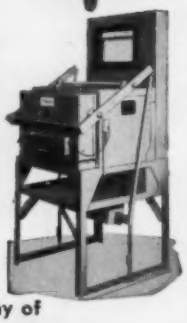
Recirculating Air Draw: box type furnace for controlled heating to 1300° F.—steel tempering, glass annealing, etc. 8 sizes to 24" w. x 15" h. x 48" d.

Bench Type: for tools and small parts—to 2000° F. 14 sizes to 10" w. x 8" h. x 18" d.

Recirculating Ovens: for drying, finishing and industrial processing to 600° F. 5 sizes to 36" w. x 36" d. x 60" h.

High Temperature Box Furnaces: for high speed steel treating to 2500° F. 3 sizes to 12" w. x 8" h. x 24" d.

Industrial Box Furnace for general heat treating—to 2000° F. 8 sizes to 24" w. x 18" h. x 48" d.



Catalog and complete information on any of these furnaces will be gladly furnished on request.

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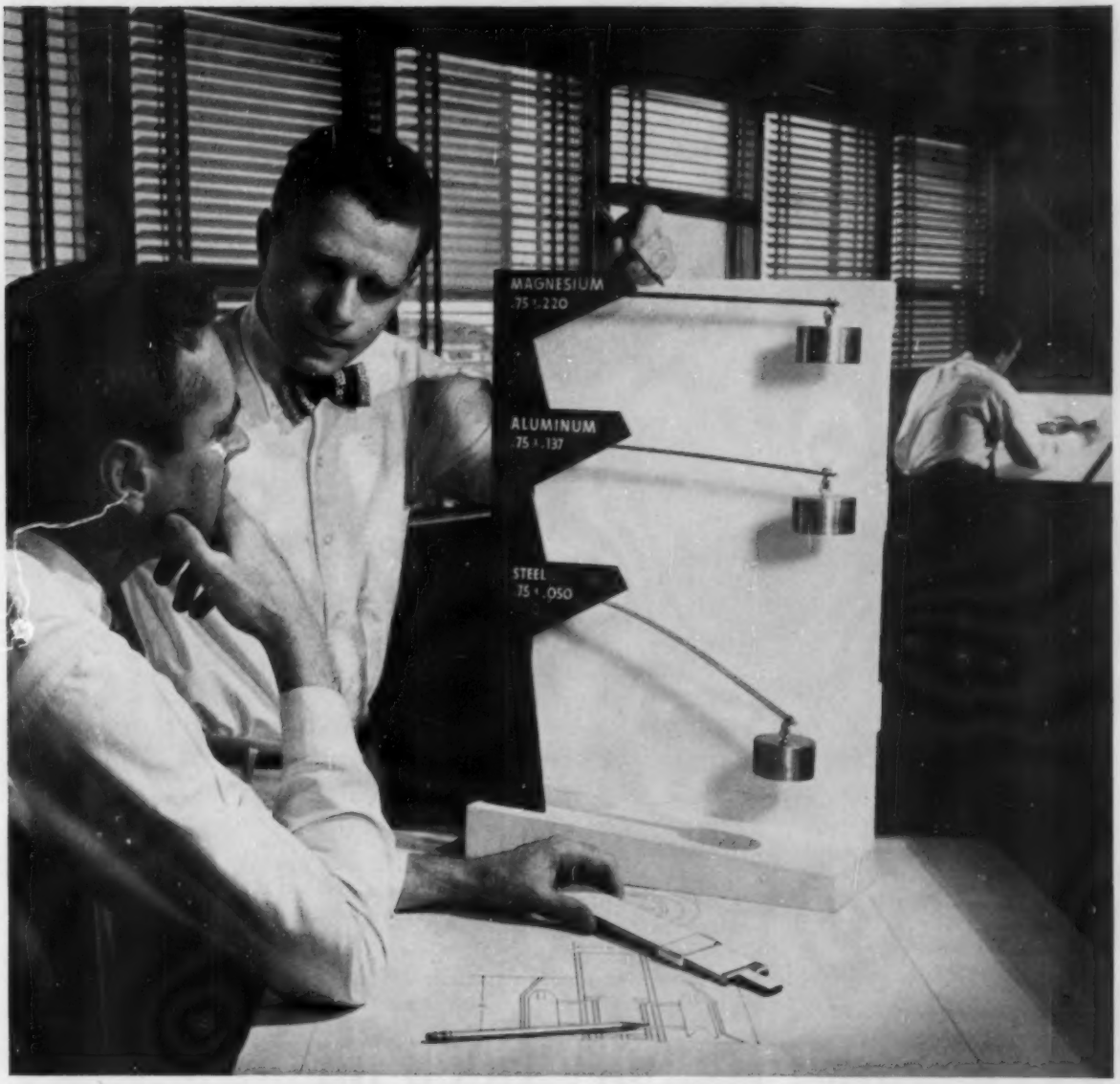

Rigidity! At equal weight, magnesium is 18 times stiffer than steel

Magnesium's unique combination of strength and light weight gives it some outstanding abilities as a structural metal. Take rigidity, for example. A magnesium bar has 22% the stiffness of a steel bar of the same dimensions.

But stiffness increases as the cube of section thickness. So, if thickness of the magnesium is increased to twice that of the steel, the magnesium bar will be over 70% more rigid—yet weigh only half as much. And if thickness is further increased until the bars are of equal weight, the magnesium bar will be 1878%—or over 18 times—more rigid!

Similarly, a magnesium bar of equal rigidity to an aluminum bar will weigh only 75% as much as the aluminum bar. At equal weight, the magnesium bar will be over twice as stiff.

From these facts it's easy to see that magnesium can do a structural job equal to or better than steel and aluminum—and with appreciable savings in weight—whenever it's practical to increase section thickness. For more information contact the nearest Dow sales office or write to us. THE DOW CHEMICAL COMPANY, Midland, Michigan, Magnesium Department, MA 1402Q.

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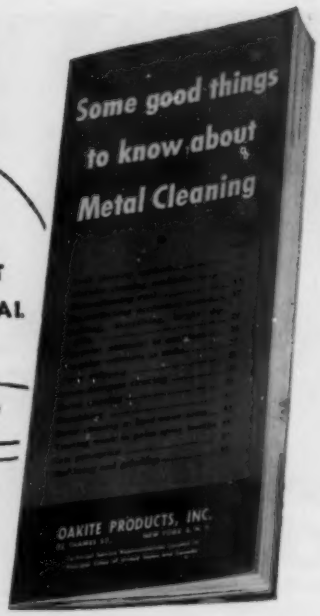
Oakite's FREE Booklet on Metal Cleaning



answers many questions that mean better production, more profit for you. Just look at the table of contents:

Tank cleaning methods
Electrocleaning steel
Electrocleaning nonferrous metals
Pickling, deoxidizing, bright dipping
Applying iron phosphate coatings in preparation for painting
Applying zinc phosphate coatings
Cleaning, removing rust and conditioning for painting in one operation
Machine cleaning methods
Paint stripping
Steam-detergent cleaning
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You'll want to know the answers

Can one cleaning material do all metal-cleaning jobs? *See page 5.*

What kind of cleaner attracts both oil and water? How does this help remove buffing compound residues and pigmented drawing compounds? *See page 8.*

Why clean ferrous and nonferrous metals in separate tanks? *See page 10.*

What are the advantages of reverse current for electrocleaning steel? *See page 15.*

For electrocleaning nonferrous metals, what are relative advantages of cathodic, cathodic-anodic and soak-anodic cleaning? *See page 17.*

Can you electroclean brass without tarnishing? *See page 18.*

How do bright dips make metals brighter? *See page 21.*

Can you clean steel and condition it for painting for less than 20 cents per 1,000 square feet? *See page 24.*

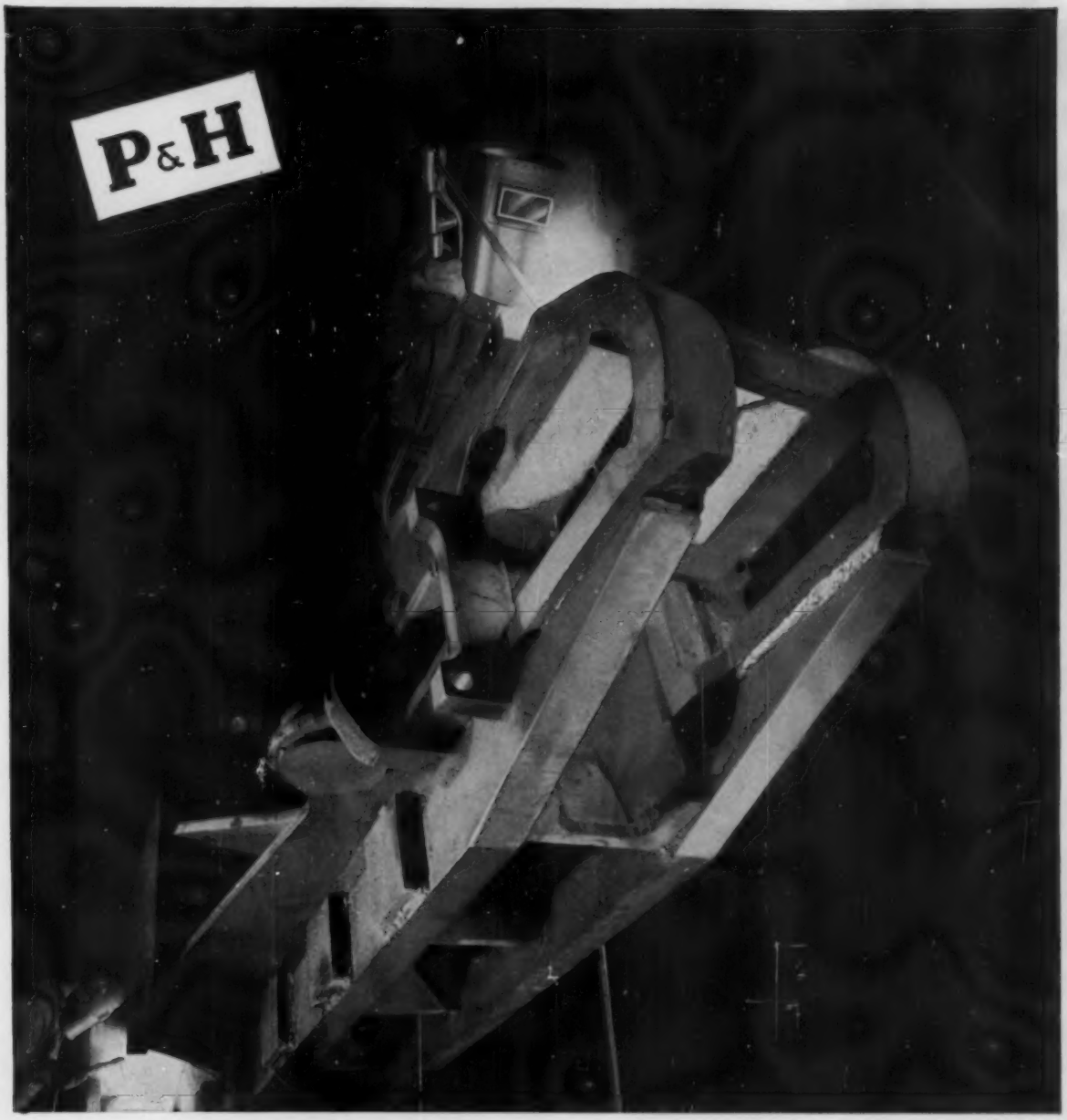
Would you like a cleaner that removes rust and oil at the same time; often eliminating all need for pickling? *See page 28.*

What's the best way to clean parts that are too large to be soaked in tanks or conveyed through washing machines? *See page 30.*

Does your burnishing barrel produce a luster you are proud of? *See page 32.*

What do you do when the overspray neither sinks nor floats in the wash water in your paint spray booth? *See page 35.*

Do you dry steel parts before anti-rusting? *See page 37.*



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High-production *quality* welds are easy for the operator who uses P&H Iron-Powder Electrodes. Powdered metal in the coating raises thermal efficiency, providing speed of deposition and bead smoothness that approach submerged arc welding.

Typical applications include railroad cars, construction equipment, bridges, shipbuilding, foundry equipment, tanks, and piping.

Write for Bulletin R-29, "P&H Smootharc Welding Electrodes," for full description and specification data. Address Dept. 312E, Harnischfeger Corporation, Milwaukee 46, Wisconsin.

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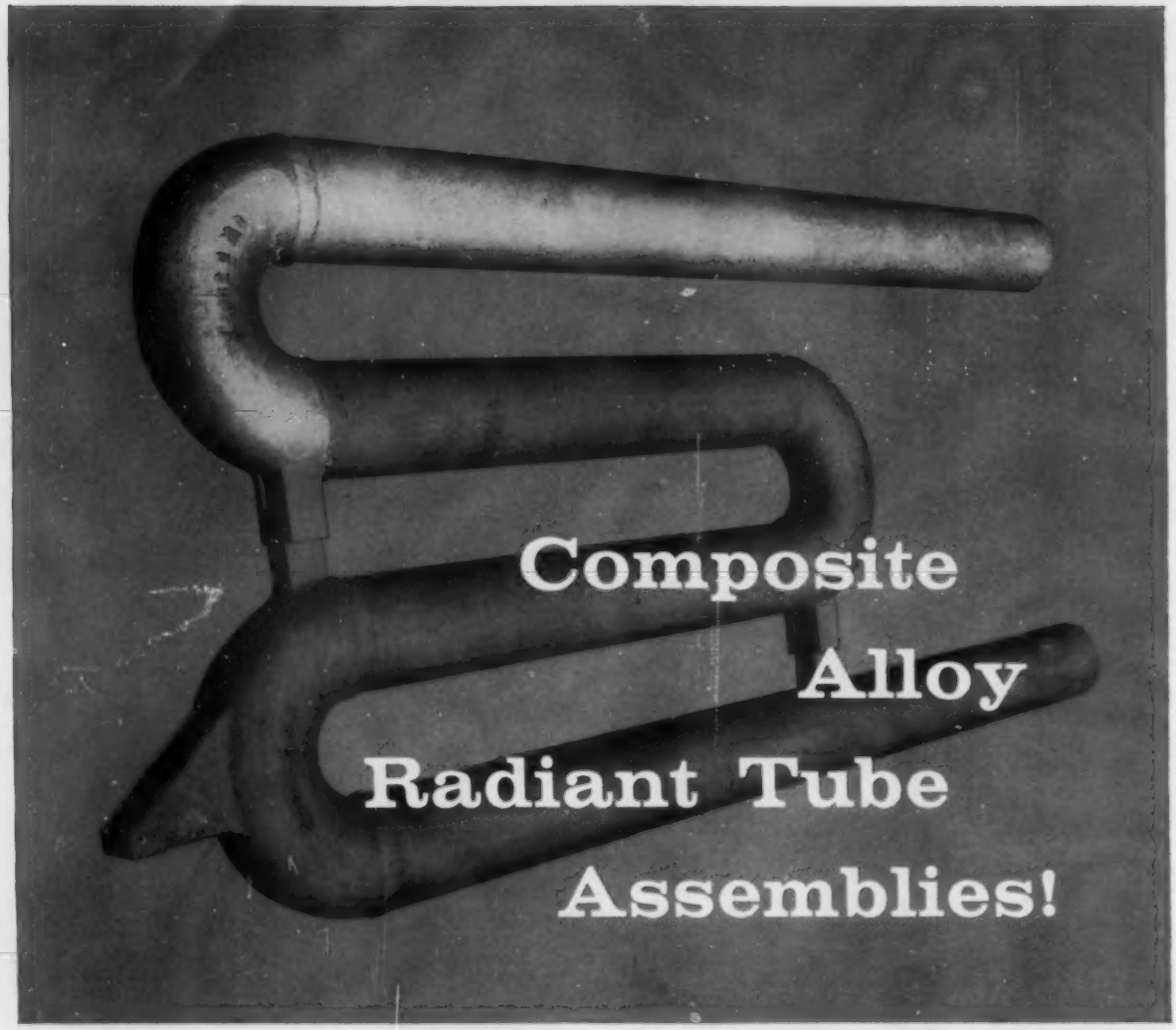

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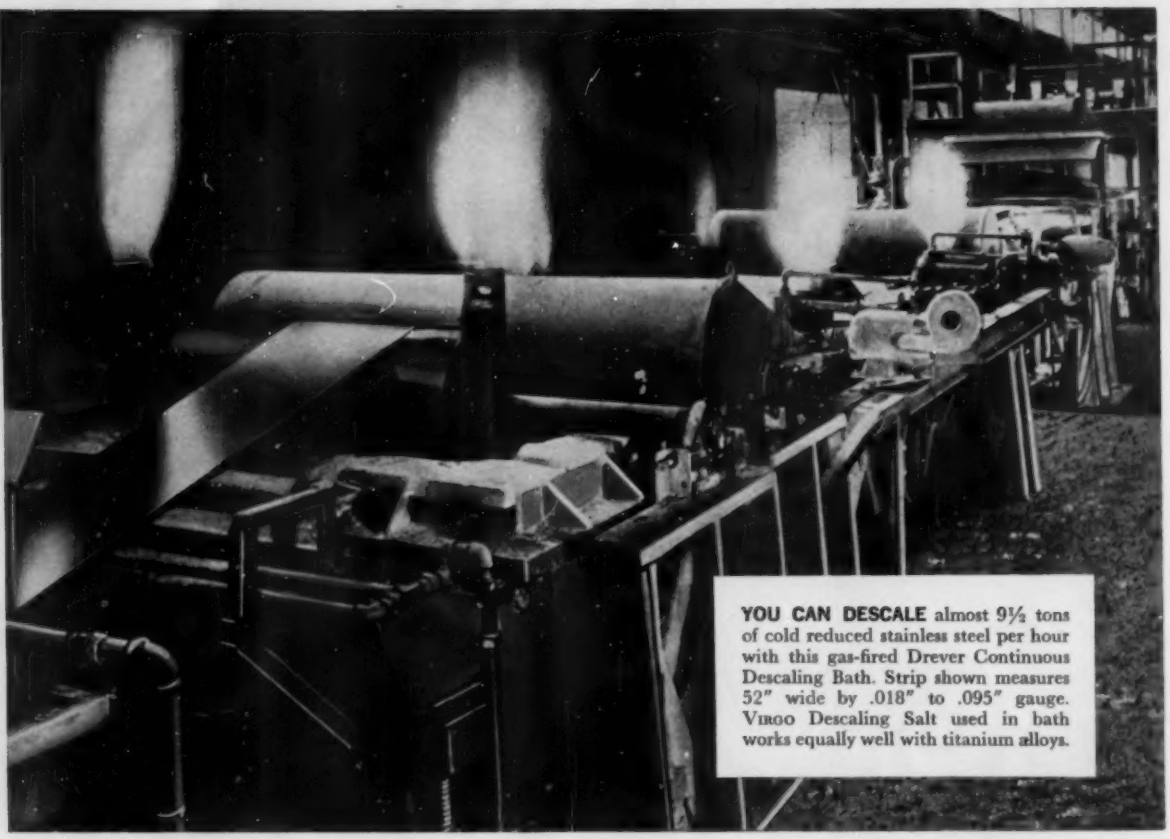

YOU CAN DESCALE almost 9½ tons of cold reduced stainless steel per hour with this gas-fired Drever Continuous Descaling Bath. Strip shown measures 52″ wide by .018″ to .095″ gauge. VIRGO Descaling Salt used in bath works equally well with titanium alloys.

VIRGO® SALT descales 18,700 lbs. of stainless strip in one hour

You, too, can accelerate your descaling speed to synchronize with production, when you use VIRGO Descaling Salt.

Equally important are the economy and safety you get when you use VIRGO.

Steel and titanium—one bath • You can descale both stainless steel and titanium alloys with the same salt bath.

Fast • The salt is so effective in making surface coatings acid-soluble, that you can remove the coating in one-tenth to one-hundredth the usual pickling time.

Safe for metals • VIRGO Descaling Salt reacts only with scale—and with no loss of base metal. There is no danger of hydrogen embrittlement when descaling titanium.

Safe for personnel • The VIRGO bath is simple and safe to operate when normal precautions are observed. Bath temperatures range from 800° to 1250°F., depending on the application.

Any form • Descale strip, sheet, bars, wire, tubes, or any other form to a chemically clean surface.

Acid disposal less of a problem • You can reduce the problems of spent acid disposal since the VIRGO process decreases acid consumption.

To find out more specifically how VIRGO Descaling Salt gives you bright, clean surfaces—at speeds to match your production requirements—write for Bulletins 25 and 25-T, stating the application you are considering.

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Desanding • Use VIRGO Electrolytic Salt to remove sand, graphite, other impurities —produce a chemically clean surface.

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Wrought Inconel carbo-nitriding basket still in use after 29 months

This Inconel* nickel-chromium alloy basket is built by Rolock, Inc. for the Progressive Metal Treating Co., Bridgeport, Conn.

Progressive uses it for carburizing, nitriding and annealing small steel parts in their Ipsen gas-fired, batch-type furnaces.

After 29 months of continuous heat-treating service it *still* has plenty of life left, despite the fact that it's already outlasted previous baskets four to one.

The basket's twin has done just as well. Ten others, purchased later are expected to do the same.

Inconel alloy contributes four ways to long life

In this instance, Inconel alloy overcomes (1) early weld failures; (2) excessive oxidation; (3) the thermal shock of 1750°F to 150°F oil quenches; (4) progressive losses in initial strength due to corrosion.

Inconel alloy also contributes a high strength-to-weight ratio. Light as they are, the baskets can easily handle the 340-pound work loads.

For information on other successful ways to increase the life of heat-treating equipment with Inconel alloy, write for the Inco booklet, "Keeping Costs Down as Temperatures Go Up."

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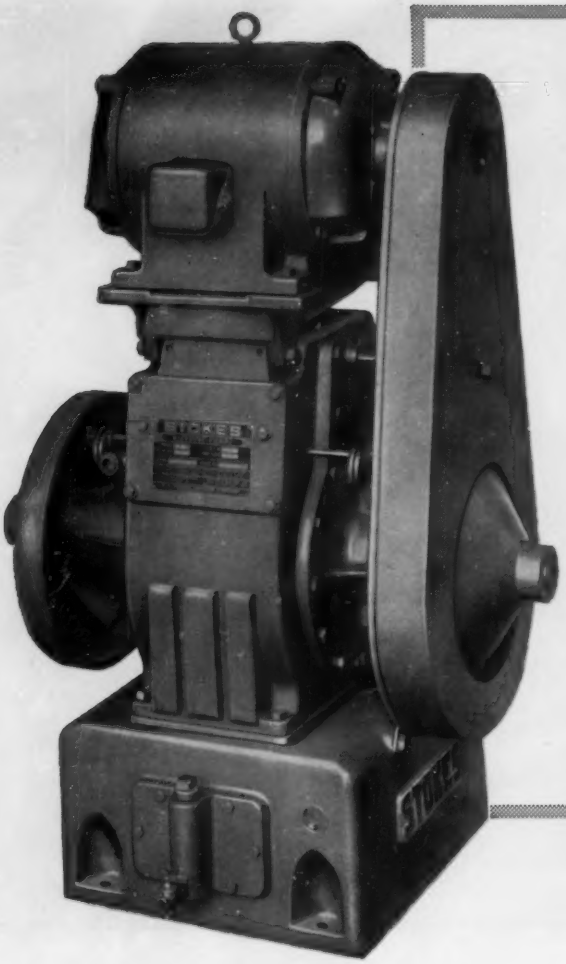

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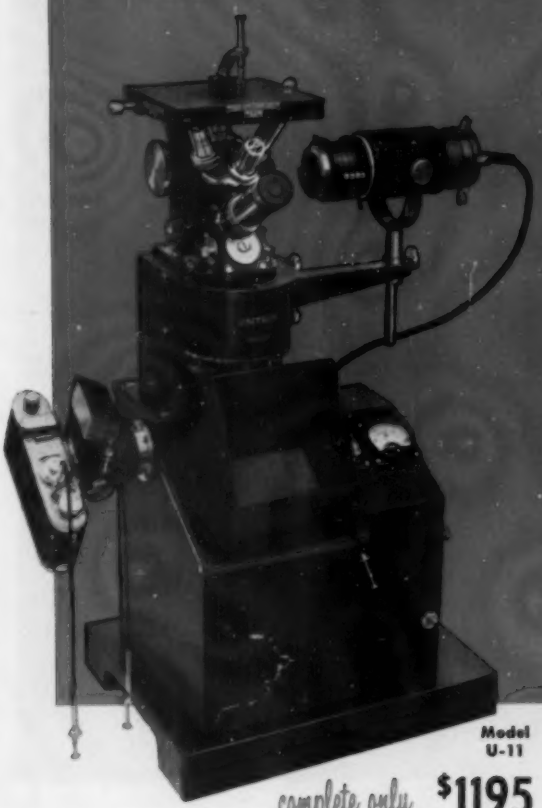

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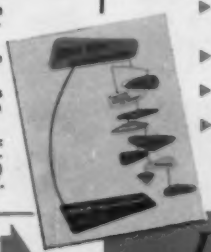
- Calibrated polarizing apparatus, 5 filters, dustcover, cabinet, etc. all included.
- Additional accessories available at extra cost include: 35mm camera attachment; K20X eyepiece for 2000X; transmitted-light accessories for transparent specimens; vacuum heating stage.



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Vacuum-melted metals are the answer to jobs where surface is critical—like gauge blocks, plug and ring gauges, rolls for aluminum foil—as well as many other specially demanding applications. They're available in most grades and sizes, including special ferrous and non-ferrous alloys. Write now for a free analysis sheet on which to describe your application. It will help us both decide how vacuum-melted metals can serve you best. *Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, New York.*

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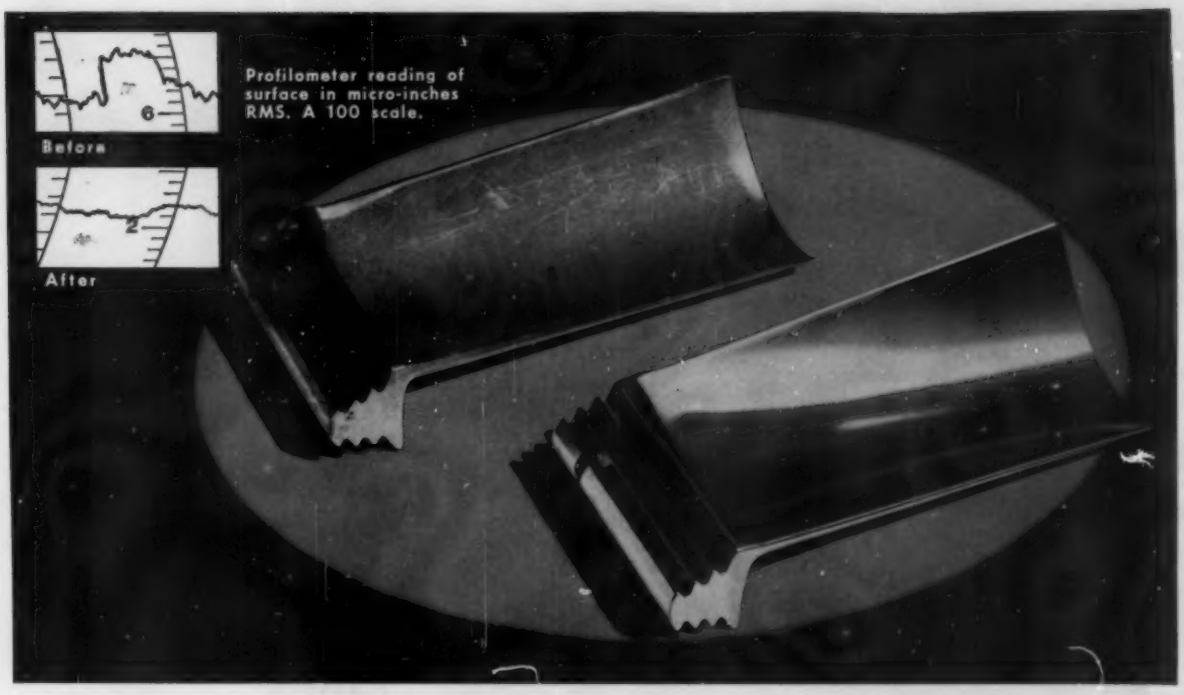
Division of Crucible Steel Company of America



Cut parts finishing costs, maintain exact tolerances, get absolute uniformity with *Roto-Finish* processes

Roto-Finish, pioneers in precision barrel finishing, offer you a complete finishing service. Savings on deburring, descaling, grinding, polishing, coloring and surface improvement are tremendous. Expensive hand finishing methods can be eliminated.

Roto-Finish processes are controlled to produce the finish you need with no significant dimensional changes. You get absolute uniformity of finish in quantity lots.

Many prominent manufacturers now using Roto-Finish processes are saving money on finishing costs. (Names on request).

ROTO-FINISH CHIPS, COMPOUNDS AND MACHINES ARE OF THE HIGHEST QUALITY Roto-Finish has never sacrificed quality for the sake of price. Through the years, Roto-Finish has carried on a continuous program of process and product improvement to meet the needs of modern industry. When you choose Roto-Finish processes, you can be sure that you are getting the best in supplies, equipment and complete continuing engineering service.

ROTO-FINISH GUARANTEES RESULTS

There is no costly trial and error involved in the purchase of Roto-Finish equipment. You submit unfinished parts to Roto-Finish along with a finished sample and a description of the finish you require. These sample parts are processed in the Roto-Finish Sample Processing Laboratories, where experienced engineers determine the combination of chips, compounds, and machine required to do the job. Roto-Finish guarantees to reproduce the same results in your plant, using the Roto-Finish processes, that are achieved in sample processing. This service demonstrates for you exactly what you can gain by using Roto-Finish processes.

The sample processing service is available to help you with your finishing problem. Take advantage of this opportunity to save on finishing costs. Send samples of finished and unfinished parts and details of the type of finishing equipment available in your plant.

SEND FOR THIS FREE TECHNICAL DATA FOLDER

It describes the basic process, chips and compounds and the complete Roto-Finish line of standard and special machines.

Roto-Finish COMPANY

3721 Milham Road, Kalamazoo, Mich.

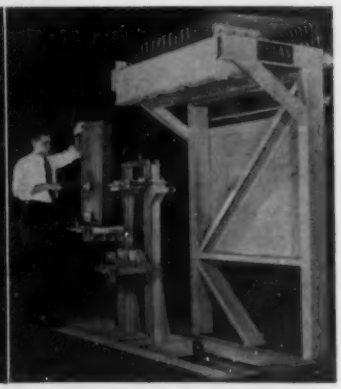
P. O. Box 988

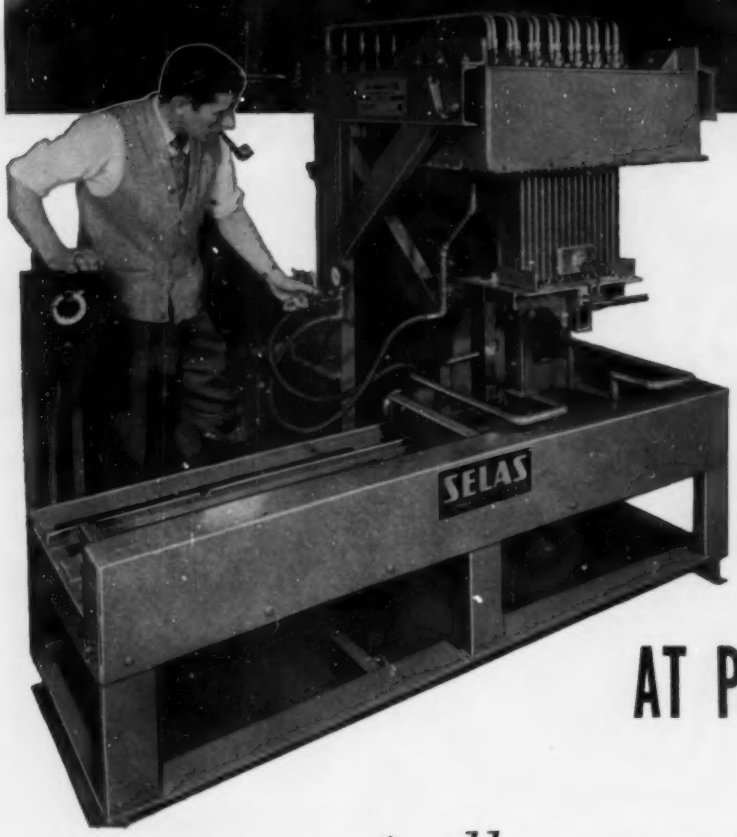
Phone: FI 3-5578

FOREIGN REPRESENTATIVES:

AUSTRALIA — A. Flavell Ltd. — 89 Tulip Street — Cheltenham
BRAZIL—Commercial E. Industrial de Fornos Werco, Ltda.—rua General Gurjao, 326—Rio de Janeiro
CANADA—Canadian Hanson & Van Winkle Co., Ltd.—Cor. Silver and Morrow Avenues—Toronto
ENGLAND — Roto - Finish Limited — Mark Road, Hemel Hempstead — Hertfordshire
FRANCE — Societe Roto - Finish — 40-42 rue Chance Milly — Clichy (Seine) — Paris
GERMANY, AUSTRIA, NORWAY, SWEDEN, SWITZERLAND — Metallgesellschaft A. G. — Reuterweg 14 — Frankfurt a. M. — Germany.
HOLLAND, BELGIUM, LUXEMBURG — N. V. Roto-Finish Maatschappij — Rotterdamseweg 370 A. Delft, Holland.
ITALY — Societa Roto - Finish a R. L. — Sesto S. Giovanni — Viale E. Marelli, 31 — Milan
SPAIN — Institute Electroquimico, S. A. — Corcega 58 — Barcelona

These Selas-designed, Selas-built brazing machines do essentially the same job . . . silver-brazing tube return-bends to the copper tubes of aluminum-finned coils. Both machines are manually-loaded and unloaded, both employ automatic cycling and Duradiant* air-gas burners. Each is quickly adjusted to accommodate a variety of workpiece sizes, brazing all the joints of each coil simultaneously. The small machine brazes coils from 13 to 22 in. high at the rate of 40 per hr. The larger machine, in which workpieces are mechanically conveyed, handles coils up to 5 ½ ft. high at the rate of 30 per hr.





AIR-CONDITIONER COILS SELAS-BRAZED AT PRODUCTION RATES

. . . automatically or semi-automatically

Selas precise temperature control and heat placement . . . targeting heat exactly where needed and only where needed . . . brazes coils at high production rates using low-cost gas and air. These specially-designed, custom-tailored machines form pressure-tight brazed joints without damage to the easily-melted aluminum fins. Yet heat input is sufficiently high to overcome, during brazing, the natural ability of heat exchangers to draw heat away from the joint area.

Whatever your brazing needs, Selas will design, engineer and build fully-automatic or semi-automatic equipment for you . . . after simulating your production conditions, using your workpieces, in our laboratory. You get speed, versatility, reproducible uniformity. High labor skills are not required because Selas builds the skills into your machine. And, since Selas designs, constructs, starts-up and services each machine, problems usually associated with divided responsibility are eliminated.

Send for Bulletin No. 36 "Production Brazing and Soldering" and reprints "Gas-Fired Machine Brazing" and "Mechanical Heating Puts Brazing on the Production Line."

SELAS
CORPORATION OF AMERICA
DRESHER, PENNSYLVANIA

Heat and Fluid Processing Engineers
DEVELOPMENT • DESIGN • CONSTRUCTION

....A Notable Coincidence

The Second World Metallurgical Congress

Entries Will Be Expected From All Over the World— —Display Your Best Work

RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard; maximum dimensions 14 by 18 in. (36 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the face of the mount giving:

Classification of entry.

Material, etchant, magnification.

Any special information as desired.

The author's company affiliation and postal address of the exhibitor should be placed on the back of the mount.

Entrants living outside the U. S. A. should send their micros by first-class letter mail endorsed "Photo for Exhibition—May be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 15, 1957, either by prepaid express, registered parcel post or first-class letter mail, addressed:

Metallographic Exhibit
American Society for Metals
7301 Euclid Ave.
Cleveland 3, Ohio, U.S.A.

CLASSIFICATION OF MICROS

(Optical and Electron)

Class 1. Irons and steels.
Class 2. Stainless steels and heat resisting alloys.
Class 3. Aluminum, magnesium, beryllium, titanium and their alloys.
Class 4. Copper, nickel, zinc, lead and their alloys.
Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.
Class 6. Metals and alloys not otherwise classified.
Class 7. Series showing transitions or changes during processing.
Class 8. Welds and other joining methods.
Class 9. Surface coatings and surface phenomena.
Class 10. Results by unconventional techniques (other than electron micrographs).
Class 11. Slags, inclusions, refractories, cermets and aggregates.
Class 12. Color prints in any of the above classes. (No transparencies accepted.)

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $100, will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1958 if so desired.

(ASM)
Award will be the "Francis F. Lucas
Grand Prize for Excellence in Metallography"
Valued at $500.00 and Endowed by
Adolph E. Buehler

The Twelfth Metallographic Exhibit

Chicago, Illinois, November 2 to 8, 1957

Special Reports On Finishing Non-Ferrous Metals

NUMBER II—Paint Base, Corrosion-Resistant Finishing with Iridite

WHAT IS IRIDITE®?

Briefly, Iridite is the tradename for a specialized line of chromate conversion finishes. They are generally applied by dip, some by brush or spray, at or near room temperature, with automatic equipment or manual finishing facilities. During application, a chemical reaction occurs that produces a thin (.00002" max.) gel-like, complex chromate film of a non-porous nature on the surface of the metal. This film is an integral part of the metal itself, thus cannot flake, chip or peel. No special equipment, exhaust systems or specially trained personnel are required.

Chromate conversion coatings are well known and accepted throughout industry as an economical means of providing corrosion protection, a good paint base and decorative finishes for non-ferrous metals. However, continued developments have been so rapid and widespread that many manufacturers may not be completely aware of the breadth of application of this type of finish. Hence, this digest of current information; to bring you up to date on the many ways in which you can obtain proper surface preparation for painting and increase product durability with a single multi-purpose chemical pretreatment. Report I on decorative, corrosion-resistant finishes and Report III on chemically polished, corrosion-resistant finishes are available on request.

First, it is an accepted fact that metal surfaces should be prepared before painting to make possible an efficient paint system. Naturally, this preparation should provide for good initial paint adhesion. Chemical treatments have proved extremely effective in this respect, particularly those of a neutral or preferably acid nature. Further, to be most efficient, chemical treatments should provide a non-porous barrier to maintain adhesion by sealing the metal from the paint and moisture. They should also provide a self-healing film which prevents lateral corrosion in the event that bare metal is exposed through scratching.

The Iridite chromate conversion coatings meet all these requirements. Iridite is a chemical conversion treatment for surface preparation. It provides initial paint bonding by molecular adhesion. It is acid in nature and produces a film that is gel-like and non-porous in structure. Thus, the Iridite film effectively seals the metal from the paint and from moisture penetration. Because the film contains certain relatively soluble constituents, it will protect areas scratched through to bare metal and prevent lateral corrosion. This is accomplished by a gradual leaching of these constituents into the damaged area.

Further, because of its gel-like, non-crystalline nature, the Iridite film will not affect the appearance or texture of the paint film, nor will it dust or powder to mar the painted surface. Because the film is non-porous, paint coverage is increased, thus substantial savings in paint costs will be realized. In addition, treated parts may be stored for long periods of time prior to painting without the risk of entrapped moisture causing blistering when painting.

Iridite chromate conversion coatings are widely used with equal ease and success under both baked and air-dried paint systems. While the actual adherence properties of the Iridite film do not increase appreciably with its thickness, corrosion protection does. The protection of the Iridite film is proportionate to its thickness and should be taken into consideration when selecting the Iridite to meet your needs. However, it is sometimes necessary to sacrifice maximum corrosion protection for appearance when a finished part is to be only partially painted. For example, it may be desirable to use a thin, clear, bright Iridite film if the unpainted areas must present a chrome-like appearance. A typical case is that of instrument housings on which the exterior is painted and the inside left unpainted.

On the other hand, if all surfaces of the product are to be painted and maximum corrosion protection is required, the heavier and most protective Iridite films should be used. For example, all surfaces of zinc die cast fruit juicers are finished with a highly protective Iridite film prior to painting to provide maximum resistance to the corrosive action of fruit juices.

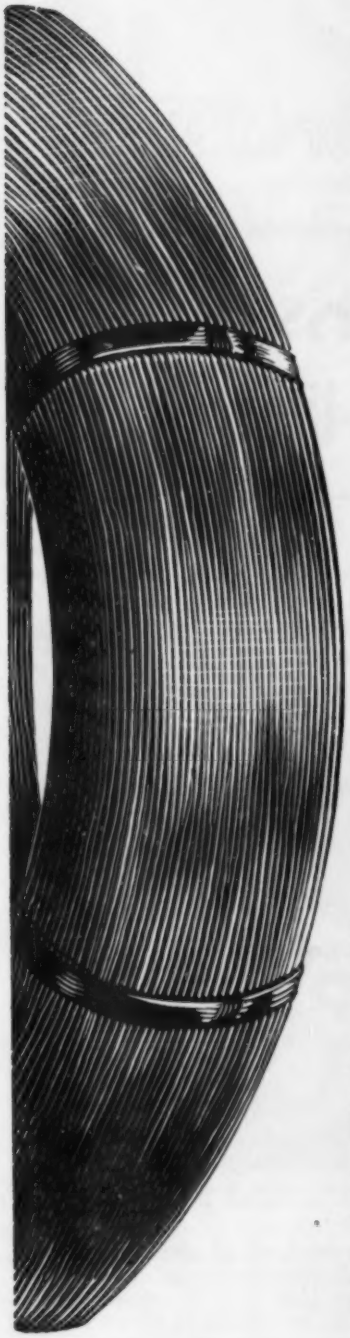
Iridite finishes are now available for all commercial forms of the more commonly used non-ferrous metals, including zinc, cadmium, aluminum, magnesium, silver, copper, brass and bronze. In addition to providing an excellent base for paint, the Iridite films also have high decorative value when used as final finishes in themselves.

These films can produce a wide variety of pleasing appearances including clear bright, iridescent yellow, bronze, olive drab and brown. In addition, many films can be modified by bleaching or by dyeing. Among the dye colors available are various shades of red, yellow, green, blue or black.

In planning or designing, you should consider the many other characteristics of Iridite finishes which may enter into the specific problem. In addition to their functions as protective and decorative finishes, and as bases for organic finishes and bonding compounds, Iridites have low electrical resistance. Some can be soldered and welded. The film does not affect the dimensional stability of close tolerance parts.

Iridites are widely approved under both Armed Services and industrial specifications because of performance, low cost and savings of materials and equipment.

You can see then, that with the many factors to be considered, selection of the Iridite best suited to your product requires the services of a specialist. That's why Allied maintains a staff of competent Field Engineers—to help you select the Iridite to make your installation most efficient in improving the quality of your product. You'll find your Allied Field Engineer listed under "Plating Supplies" in your classified telephone book. Or, write direct and tell us your problem. Complete literature and data, as well as sample part processing, is available. Allied Research Products, Inc., 4004-06 East Monument Street, Baltimore 5, Maryland.



209 DIFFERENT KINDS OF WIRE

. . . *and Youngstown Makes Them All*

No matter what type wire you require, Youngstown should be your specification for high quality, uniformity and dependability. That's because they are all drawn from specially refined open-hearth carbon steels to meet your most exacting specifications.

Every grade of Youngstown Wire is rigidly quality-controlled in all steps of its production from ore mining to finish drawing and coating. This guarantees you a uniform product—both chemically and physically—that's free from injurious seams and piping, laps, die marks, as well as internal tearing and cupping.

Why not study this listing—it may suggest new products you could make from Youngstown Wire to boost both your sales volume and profits.

For additional information or metallurgical assistance, write or phone today to your nearest Youngstown District Sales Office.

QUALITY · YOUNGSTOWN · SERVICE

THE YOUNGSTOWN SHEET AND TUBE COMPANY

Manufacturers of Carbon, Alloy and Yoloy Steel

General Offices - Youngstown 1, Ohio

District Sales Offices in Principal Cities

Aircraft Wire
Alloy Wire
Annealed Wires
Armor Wire: Armoring Wire
Artificial Flower Wire
Automotive Wire
Awl Wire
Axle Wire
Bail Wire
Bale Tie Wire
Baling Wire
Ball Pin Wire
Basic Wire
Basket Handle Wire
Bed Rods
Bessemer Spring Wire
Bicycle Chain Stud Stock
Bicycle Spoke Wire
Binding Wire
Bolt and Rivet Wire
Bond Wire
Bonnet Wire
Bookbinder Wire
Border Wire
Bottle Handle Wire
Bottling Wire
Box Binding Wire
Box Hinge Wire
Brace Wire
Brick Cutting Wire
Bright Wire
Broom Wire
Brush Wire
Buckle Wire
Bundling Wire
Button Hook Wire
Cable Armor Wire
Can Key Wire
Cap Screw Wire
Car Heater Wire
Car Seat Wire
Card Wire
Cast Steel Wire
Ceiling Hook Wire
Chain Welding Wire
Chain Wire
Chair Rods
Chair Wire
Channel Bead Wire
Channel Pin Wire
Check Rower Wire
Clasp Wire
Clip Wire
Clothes Line Wire
Clothes Pin Wire
Coat Hanger Wire
Coat and Hat Hook Wire
Coiled Spring Wire
Cold Heading Wire
Concrete Reinforcement Wire
Copper Bearing Wire
Coppered Wire
Core Wire (A.C.S.R.)
Cork Screw Wire
Cotter Pin Wire
Crimping Wire
Croquet Arch Wire
Curry Comb Wire
Curtain Rods
Damper Rods
Double Clinch Wire
Dowel Wire
Duck Bill Nail Wire
Eave Trough Hanger Wire
Edge Wire
Elevator Hoisting Cable Wire
Fence Wire
Ferrule Wire
Fine size Wire
Firing Pin Wire
Fish and Leader Wire
Flesh Fork Wire
Flexible Shaft Wire
Florist Wire
Foundry Core Wire
Frame Wire
Fruit Jar Wire
Fuse Wire
Galvanized Wire
Galvanized Armor Cable Wire
Galvanized Brace Wire
Garment Hanger Wire
Gate Hook Wire
Grape Tie Wire
Grass Catcher Wire
Guard Wire
Gun Wrapping Wire
Hairpin Wire
Handle Wire
Harness Snap Wire
Hat and Coat Hook Wire
Hat Rods
Head Lining Wire
High Carbon Wire
Hog Ring Wire
Hook and Eye Wire
Hoop Wire
Hose Binding Wire
Husking Pin Wire
Key Wire
Key Ring Wire
Key Stock
Keystone Wire
Lacing Wire
Lantern Wire
Lathing Wire
Link Wire
Lintel Wire
Lock Washer
Loop Wire
Machinery Wire
Machine Screw Stock
Manufacturers' Wire
Market Wire
Mat Border Rods
Mat Wire
Mattress Wire
Metal Stitching Wire
Muzzle Wire
Nail Head Wire
Nail Wire
Neck Wire
Neck Yoke Ring Wire
Netting Wire
Nickel Steel Wire
Non-corrosive Wire
Nut Cracker Wire
No-Sag Spring Wire
Oval Wire
Oven Rack Wire
Pail Bail Wire
Pail Rim Wire
Piano Rods
Pin Wire
Pinion Wire
Pivot Wire
Pipe Winding Wire
Plow Steel Wire
Plunger Wire
Pneumatic Tire Bead Wire
Pot Chain Wire
Poultry Netting Wire
Pump Chain Wire
Rake Tooth Wire
Refrigerator Shelf Wire
Reinforcement Wire
Riveting Wire
Rivet Rods
Rivet Wire
Rock Fastener Wire
Roll Threading Wire
Rope Wire
Saddle Spring Wire
Sash Cord Wire
Scrapless Nut Wire
Scratch Brush Wire
Screen Wire
Screw Wire
Screw Driver Wire
Screw Rod Wire
Shade Roller Wire
Shelf Wire
Skid Chain Wire
Smooth Wire
Snare Wire
Soft Processed Wire
Spark Plug Wire
Spiral Hooping
Spoke Wire
Spring Wire
Stapling Wire
Stitching Wire
Stone Wire
Stove Bolt Wire
Stove Pipe Wire
Stove Rods
Straightened & Cut Wire
Strapping Wire
Stud Stock
Surveyors' Chain Wire
Tack Wire
Tag Wire
Tie Wire
Tire Bead Wire
Towel Rods
Toy Wire
Trap Spring Wire
Transom Rods
Trellis Wire
Tuning Pin Wire
Tying Wire
Umbrella Wire
Wash Boiler Wire
Weaving Wire
Welding Wire
Whip Guard Wire
Wood Screw Wire
Wrapping Wire
Zig Zag Spring Wire

UNICHROME
Trade Mark

News about
COATINGS for METALS
Metallic.....Organic.....Decorative.....Protective

Simple bronze plating process gives gold-like finish

- ***M&T copper-tin process deposits extraordinary, golden-glow decorative plate . . .***
- ***Also cuts need for nickel as undercoat***

BRONZE plating has proved itself a practical finish in large and small installations. The copper-tin process developed by Metal & Thermit eliminates usual difficulties and disadvantages in alloy plating. It is as easy to operate and control as normal processes depositing a single metal.

Equally important, this bronze can be deposited with brilliant 24K gold color by using a trouble-free brightener. Protected with a clear organic coating, it provides a high quality decorative finish with unusual appeal and long life. Overall cost of this bronze rivals that of copper and is less than that of a brass plate.

M&T Bronze gets the trophies. Golden-glow finish for die cast trophy cups wins over copper-nickel-gold formerly used by leading producer.

VALUABLE UNDERCOAT

As an undercoat, M&T Bronze has these qualifications: Good corrosion resistance; hardness better than copper and virtually equal to nickel; more ductility than nickel.

Undercoat-bronze can be plated semi-bright or matte. Both buff more readily than copper and with less chance of cut-through on edges.

OPERATIONAL ADVANTAGES

M&T Bronze offers better than twice the speed of fast copper plating solutions. There are numerous installations working at normal current densities of 60-75 amps per sq. ft. Densities of 100 amperes deposit over one-tenth mil a minute smoothly.

Golden-glow bronze delivers uniform color on intricate decorative work. So outstanding is its throwing power, it is being used to replace copper on complex automobile parts. It uses single anode circuits, and copper anodes which corrode uniformly. The tin is supplied by potassium stannate additions, assuring simple, economical control of the process.

For an unusual finish, both in appearance and protective function, the golden-glow M&T Bronze Process offers interesting possibilities to metal finishers and designers. Send for data.

New economy in chromate finishing

Several newly developed Unichrome Dip Compounds work at extreme dilutions. They offer chromate solutions with still lower make-up and operating costs than previously delivered by economical Unichrome Dips. These new Dips make it practical to preserve shelf life and appearance of galvanized, zinc plated or die cast items, even those having low unit price or narrow margin of profit.

MATCHED TO THE NEED

Unichrome Dip Solutions form corrosion-resistant finishes integral with zinc, improve and protect its eye appeal.

But chromate dips are active solutions which strip away zinc as well as convert its surface into an attractive but inactive film. As a result, the type of equipment used and the operating time or cycle affect results. The differing needs of manual or automatic finishing must be satisfied to produce the color, corrosion resistance, uniformity of finish—as well as the economy desired. Since no single chromate solution is equally suitable for all applications, many specialized Unichrome Dip Compounds are made available.

Metal & Thermit will gladly recommend the proper dip to meet specific needs. Simply submit details of product and requirements.

Unichrome is a trademark of Metal & Thermit Corp.

METAL & THERMIT
CORPORATION
General Offices: Rahway, New Jersey
Pittsburgh • Atlanta • Detroit
East Chicago • Los Angeles
In Canada: Metal & Thermit—United Chromium of Canada, Limited, Rexdale, Ont.

XXI

This is the twenty-first of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

How Alloy Steels Respond to Induction Hardening

In the now-popular induction-hardening process, steel is first heated above the transformation range by means of electrical induction, then quenched as required. Special equipment is needed, and heat is developed as follows:

High-frequency alternating current passes through a coil or inductor, with the result that a magnetic field is created in the coil. When the piece to be treated is placed in this field, it is heated rapidly by induced energy. With the various types of induction-heating equipment, the process is capable of surface- or case-hardening to various controlled depths; however, through-hardening can be obtained with certain alloy steels. Ferrous metals that respond well to induction hardening include numerous grades of both alloy and carbon steels, as well as hardenable stainless steel and plain or alloyed cast iron.

As a rule, when alloy steels containing no carbide-forming elements are heated by induction, the usual hardening temperatures can be used. But with alloy steels that do contain such carbide-forming elements as chromium, molybdenum, and vanadium, the hardening temperature must be increased if shallow cases are required and the normal effect of the alloying elements is desired.

Hardness obtained by the induction process is a function of the carbon content and prior structure, just as it is when conventional heating methods are used. Nevertheless, higher surface-hardness values for a given carbon content have often been noted in parts subjected to surface induction-hardening. The extra hardness may be as much as five Rockwell C points for steels of 0.30 pct carbon.

As pointed out previously, the induction method requires special equipment. However, it possesses several marked advantages, including speed of heating and cleanliness of operation. Pieces heated by induction are usually subject to a minimum of scaling and distortion. Moreover, induction-hardening equipment is very compact and therefore conserves floor space.

If you would care to know more about the induction hardening of alloy steels, you are invited to communicate with our technical staff. Bethlehem metallurgists have made a thorough study of the subject, including the many details of quenching and tempering. Call them if they can help you in any way. And remember, too, when considering sources of alloy steels, that Bethlehem makes the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

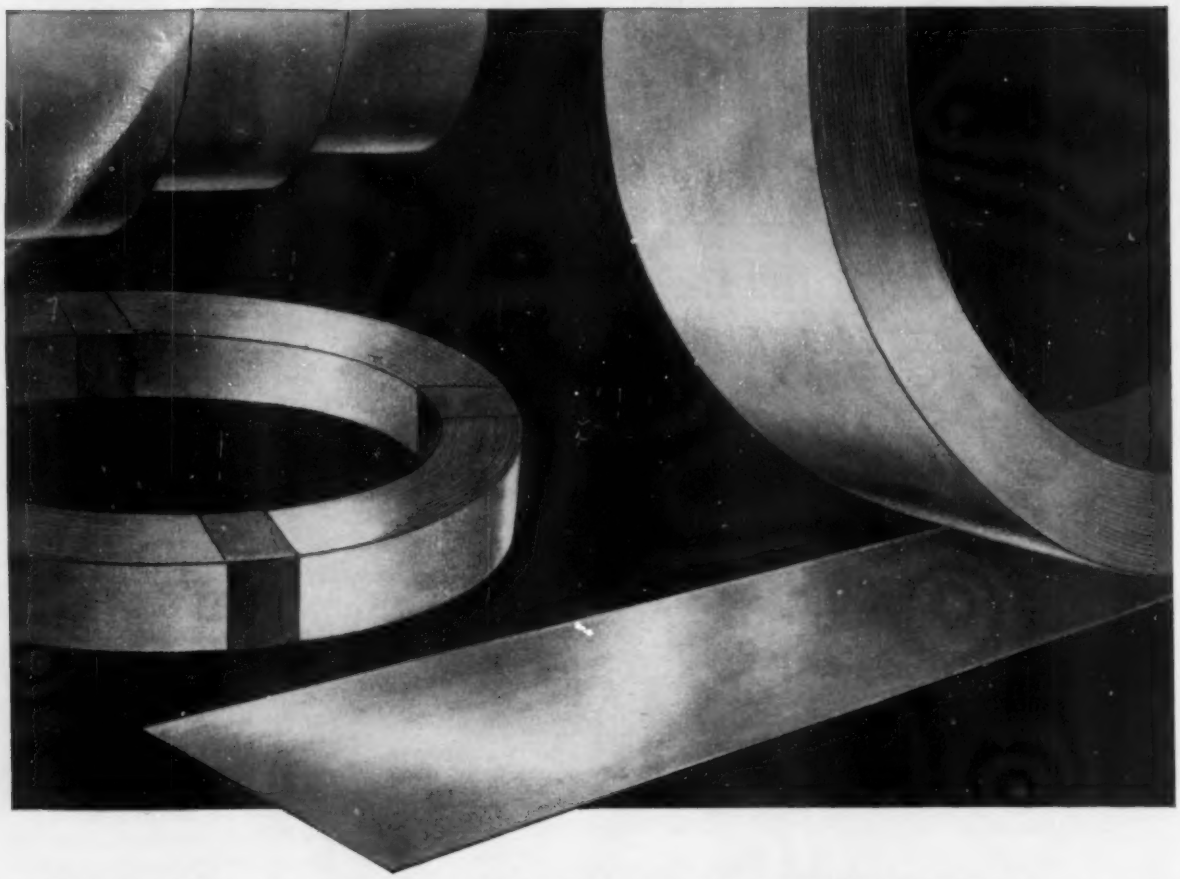
If you would like reprints of this series of advertisements from No. I through No. XX, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 20 subjects in the series are now available in a handy 36-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL



Superior Quality, Retained in YOUR Product . . . UDDEHOLM Strip Steel

Quality of materials is something that will always show up in the final product. So why not take advantage of the extra quality available in Uddeholm Swedish Strip Steel. For, besides transferring its inherent quality to *your* product, such a steel can seriously lessen production problems and rejects.

Reasons for Uddeholm Strip Steel "quality" are easy to explain. As a raw material Uddeholm uses famous Varmland iron ore, world-renowned for its exceptional purity. Added to this is a traditional craftsmanship in steelmaking almost three centuries old—where only the finest steel is accepted. Final perfection is guaranteed by a selective system of rigid inspection.

In terms of your application, then, this means cold-rolled strip steel of consistent uniformity, undeviating flatness, and fine finish—with straightness of edges and accurate dimensional tolerances throughout. And these features are combined in the grade, finish and dimensions you need, whatever your requirements. Widths range from ⅛″ to 16¼″, thicknesses from .001″ to .125″. Tolerances as close as ±.00008″ are possible. Slitting and edging facilities are also available.

Uddeholm Strip Steels appear in countless applications, including Stainless Steel products, stampings, intricate machine parts, all types of blades and springs, and many others. For quick delivery just phone us your needs.

Write for latest Strip Steel Stock List

UHB

UDDEHOLM COMPANY OF AMERICA, INC.

Tool and Die Steels
Specialty Strip Steels

Offices and Warehouses

New York: 155 East 44th Street, MUrray Hill 7-4575
Cleveland: 4540 East 71st Street, DIamond 1-1110
Los Angeles: 5037 Telegraph Road, ANgelus 2-5121

District Representatives

CHICAGO: Frank J. Mackin, Leroy E. Marshall, 55 East Washington, STate 2-1649 DETROIT: Warren H. Nugent, 17304 Lahser Road, KEnwood 5-6340
PHILADELPHIA: Frank T. Campagna, 34 South 17th Street, RIttenhouse 6-4290

Speedomax H . . . widely-read instrument with the high I.Q.*

* *Industrial Qualifications*

Compact enough to offer savings in valuable panel space, precise enough to suit exacting industrial measuring requirements, sturdy enough to stand up to rugged shop conditions . . . these qualifications are making Speedomax H "preferred reading" in an increasing number of applications throughout steel plants, foundries, and the metalworking industry.

A wide selection of ranges (for temperature, pH, gas analysis, speed, etc.), types of control and other options assures that Speedomax H—round-chart, strip-chart, or indicator—can fully meet the needs of the great majority of applications. And you'll find that our highly-standardized production techniques result in quick delivery and lowered cost.

Simplicity of installation and maintenance, interchangeability of component parts, ease of range conversion are but a few of the features that point to long-range economies as well, when you choose Speedomax H. If you haven't heard the full story on this instrument . . . if you'd like to investigate its potential for expansion or modernization of facilities . . . simply contact the L&N office near you, or write us at 4927 Stenton Avenue, Philadelphia 44, Pa.

LEEDS Instruments NORTHRUP Automatic Controls • Furnaces

PERMABRASIVE is the only pearlitic malleable iron shot and grit on the market. Pearlitic malleable iron is made with the proper analysis and controlled heat treatment. The result is malleable iron with a more durable structure and, in abrasives, "pearlitic" means a greater resistance to break down, longer life, greater cleaning ability with all the advantages of lower abrasive costs, lower maintenance costs, faster cleaning!

"Pearlitic"..... is a magic word!

National Metal has been making pearlitic malleable shot and grit for several years. Permabrasive—the only pearlitic malleable shot and grit—has been a pioneer in the field of premium quality abrasives and has saved thousands of dollars for hundreds of foundries!

Sure, Permabrasive pearlitic malleable shot and grit costs a little more per ton than ordinary annealed abrasives. That's because it costs more to make. But its use has snow-balled, because it saves money on abrasives used and cuts maintenance costs substantially. *Your* savings are *guaranteed in writing* when Permabrasive goes to work in your blast cleaning room.

*Licensed under U. S. Patent No. 2134026, U. S. Application No. 6196.42

TIRED OF TESTING?

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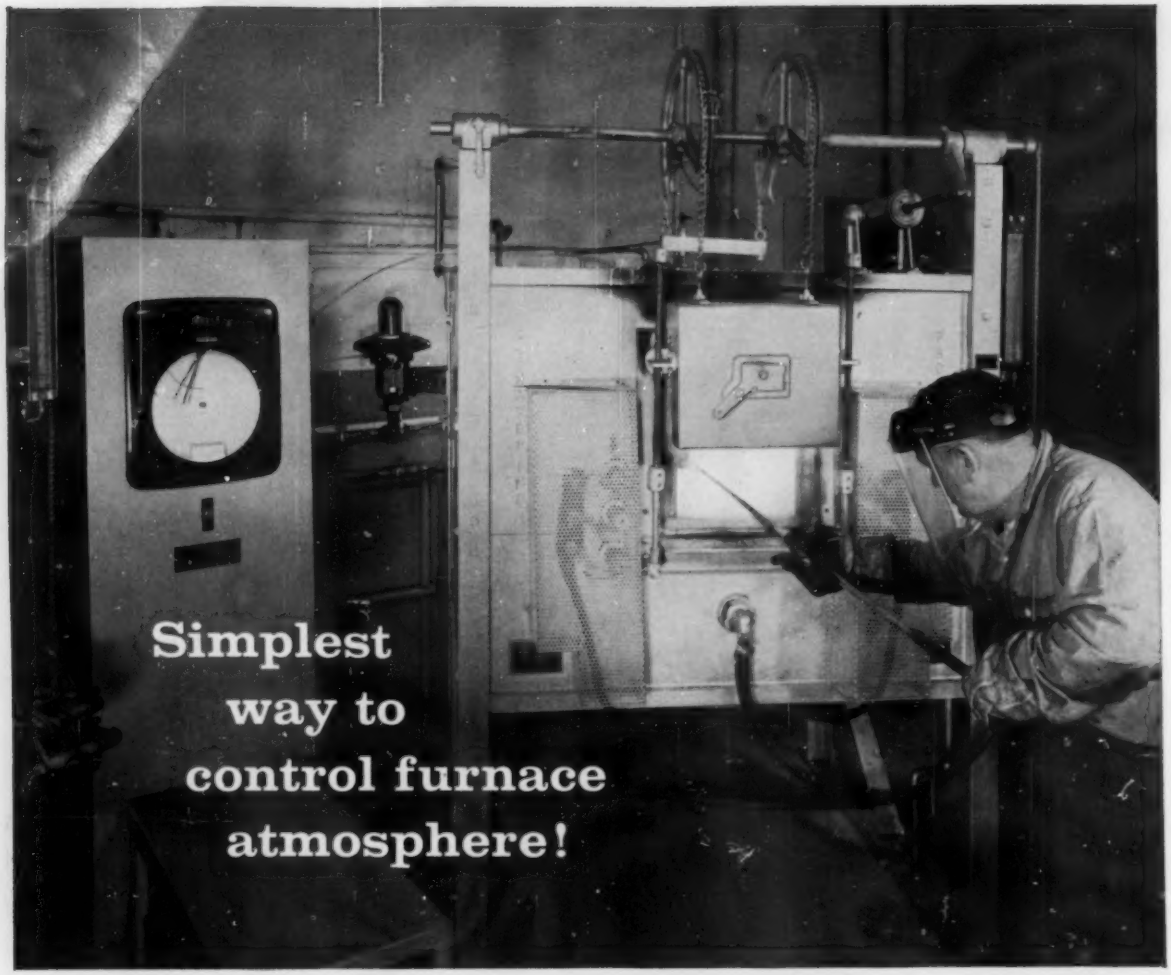

Foxboro Dew Point Control on C. I. Hayes Hardening Furnace at W. H. Nichols Company, Waltham, Mass. Gears and other parts used in the production of Nichols' rayon and nylon pumps are treated in this furnace at temperatures of approximately 2250°F. Foxboro Control Valve at right of controller precisely regulates flow of propane gas to furnace . . . holds furnace moisture at pre-set value.

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Foxboro Dew Point Control is available for measurement and control of dew point as low as —30°F dew point, and up to +142°F dew point. It provides positive protection against decarb, etching, scaling, and carbon deposit caused by incorrect atmosphere. For better production of a better product in your heat treat, get full details on Foxboro Dew Point Control. Write **The Foxboro Company 526 Neponset Ave., Foxboro, Mass., U. S. A.**

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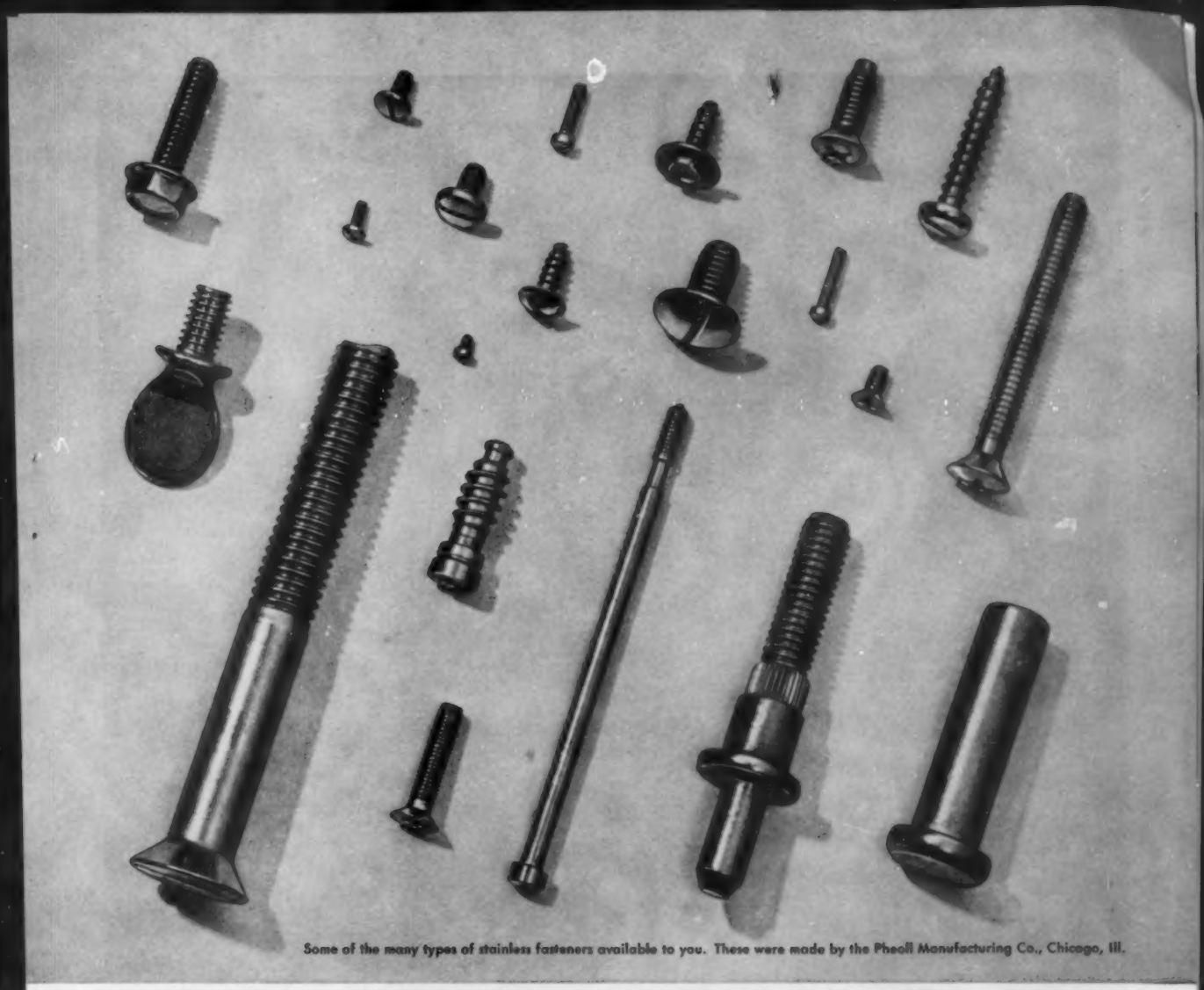

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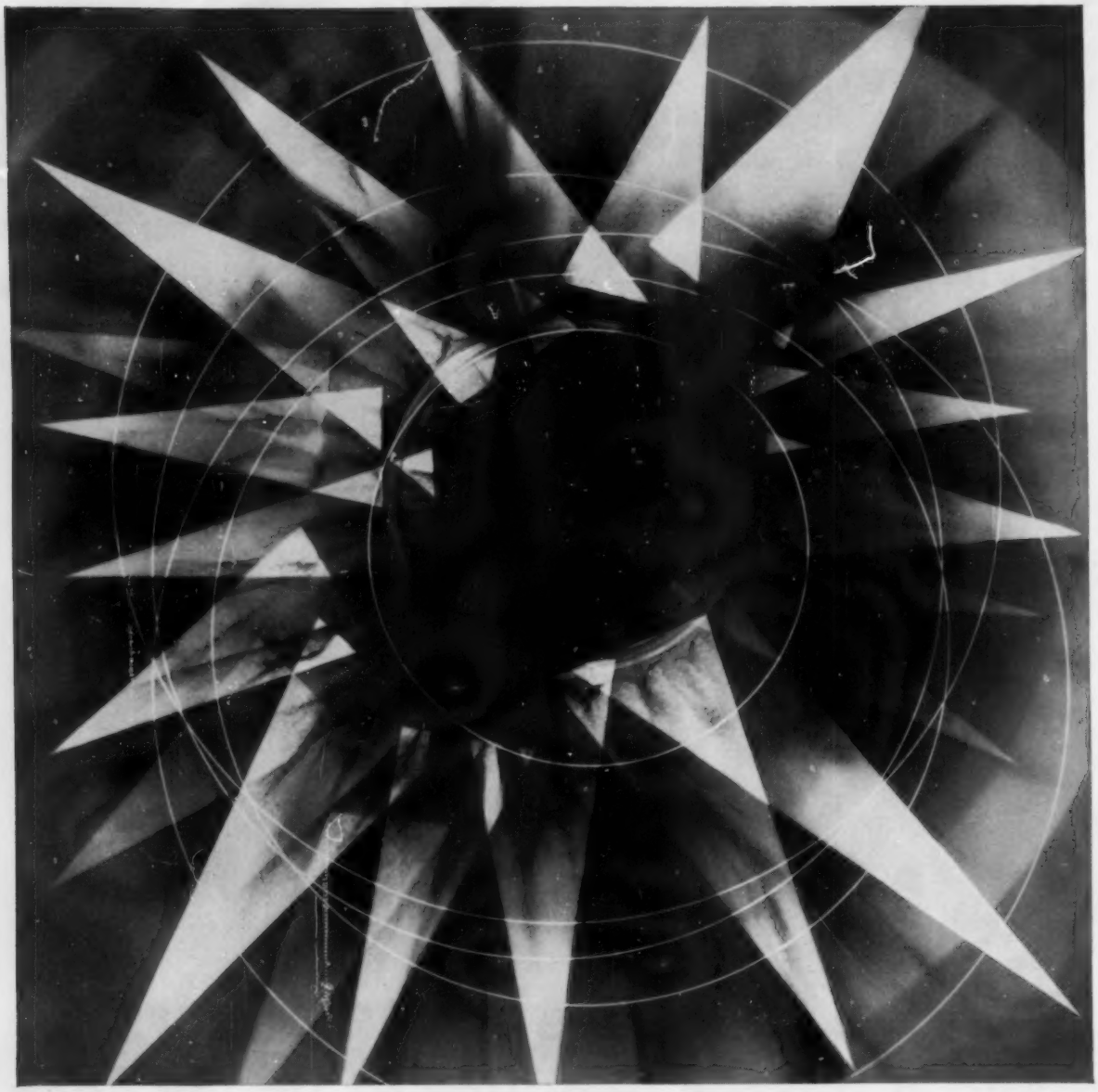

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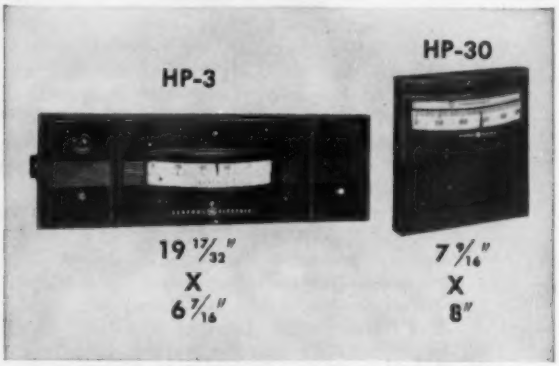
For further information, write to Section 587-8, General Electric Company, Schenectady 5, N. Y., or contact your nearest General Electric Apparatus Sales Office.



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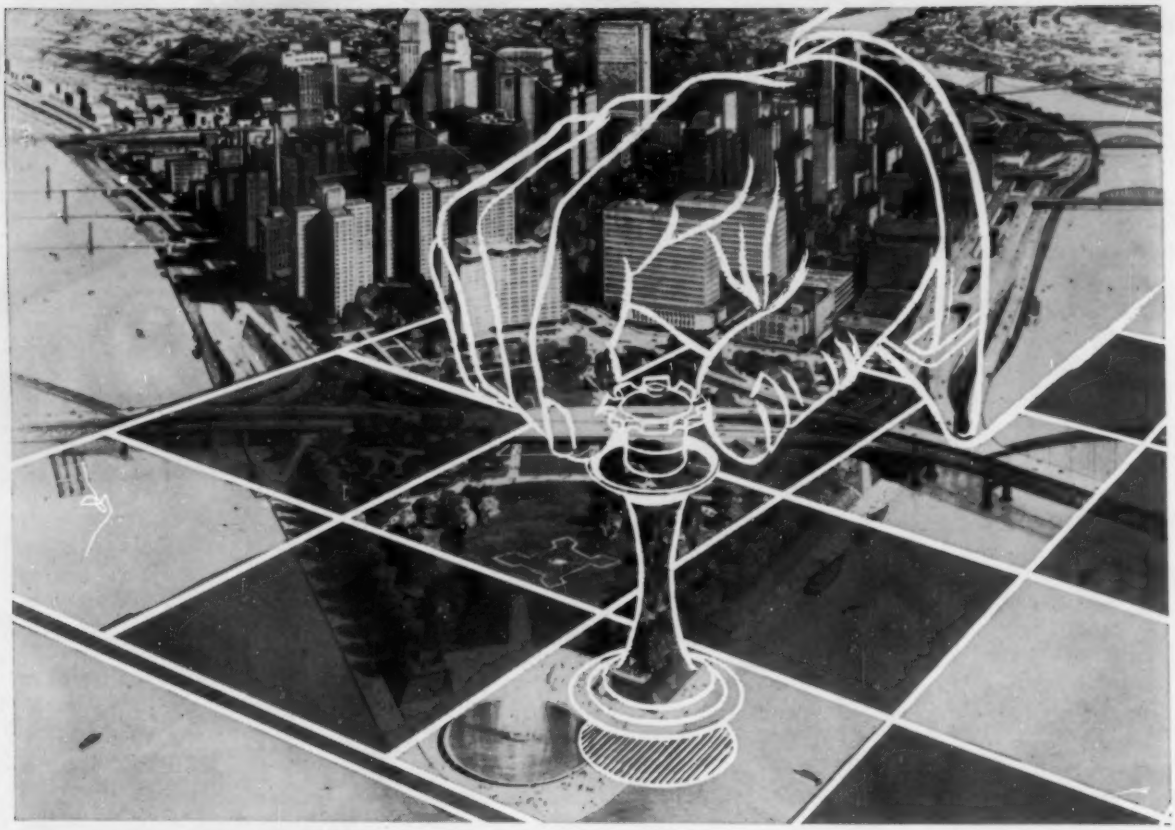

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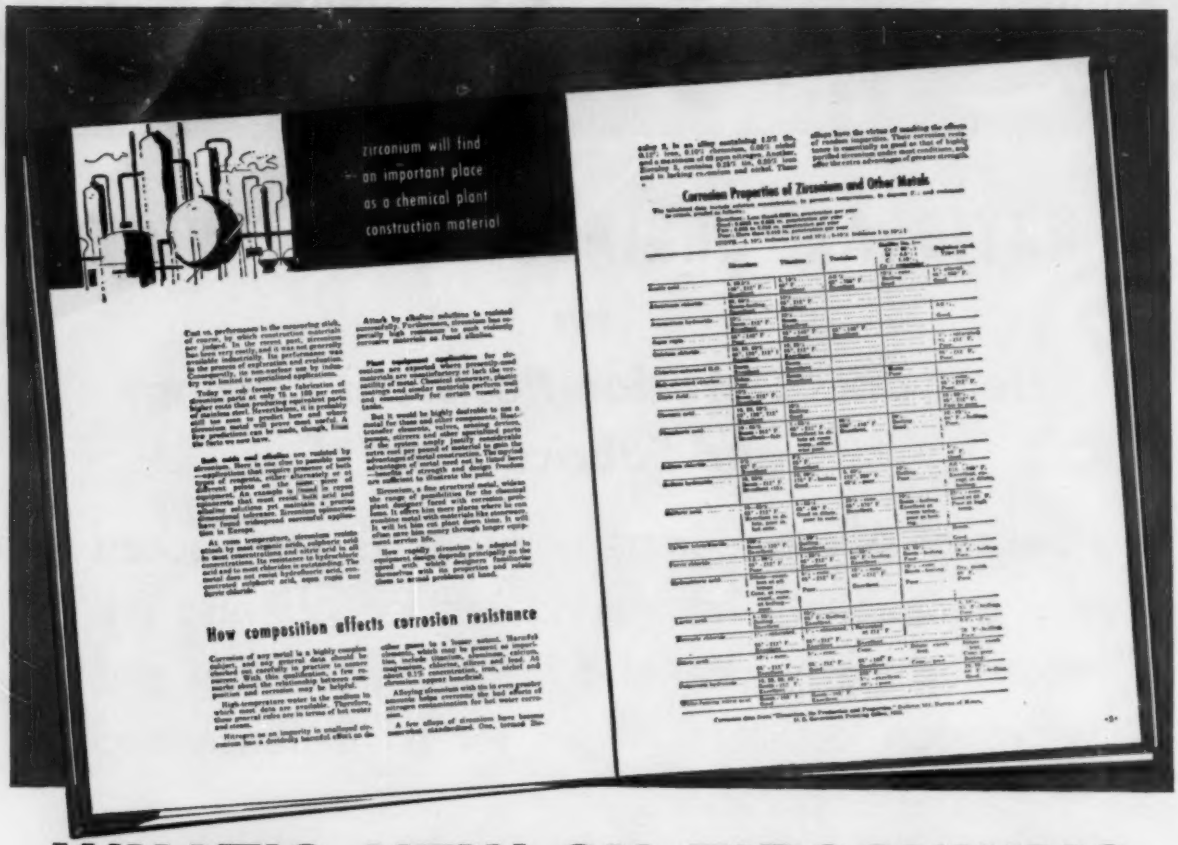
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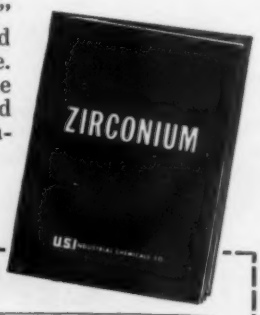

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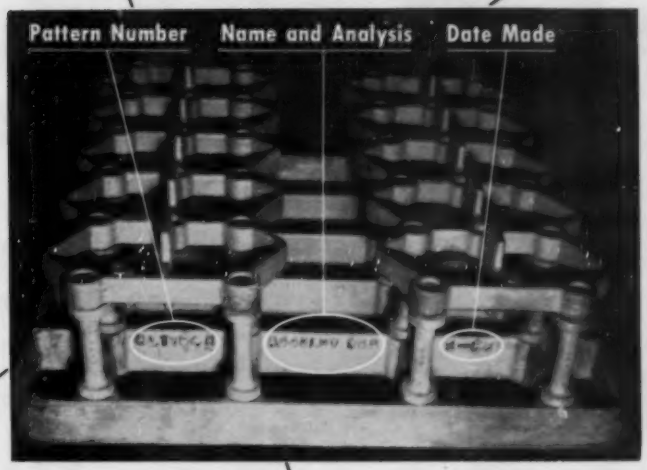

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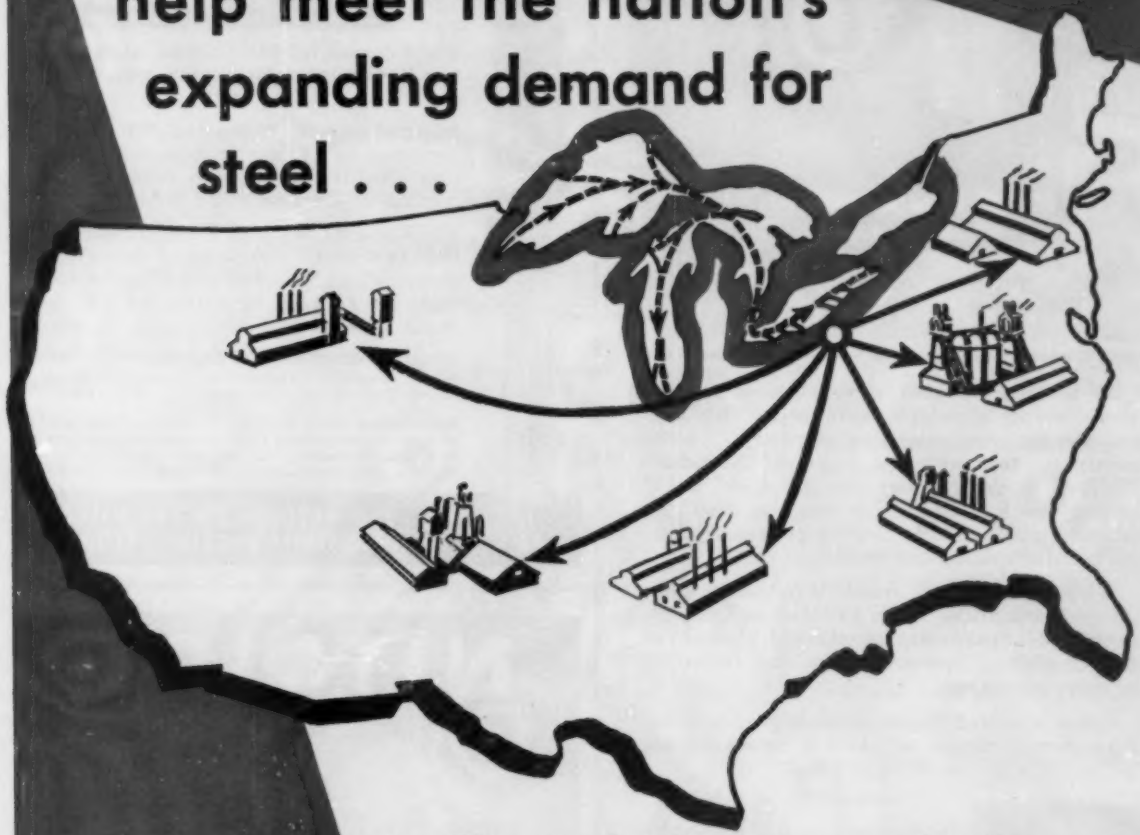

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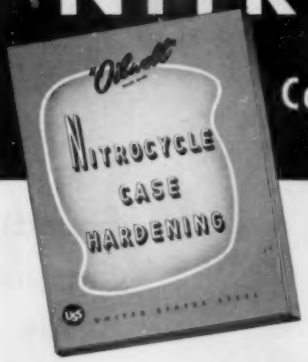

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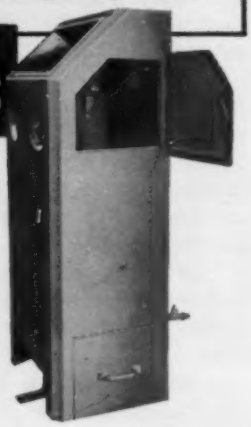

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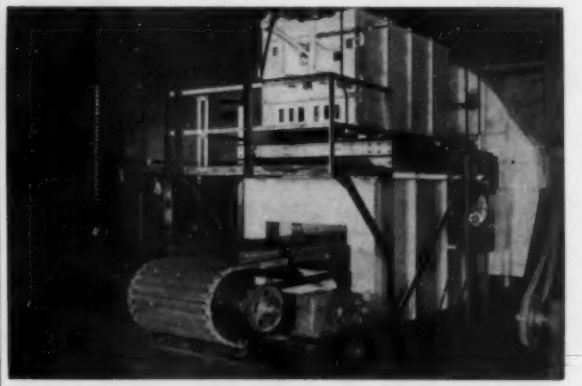

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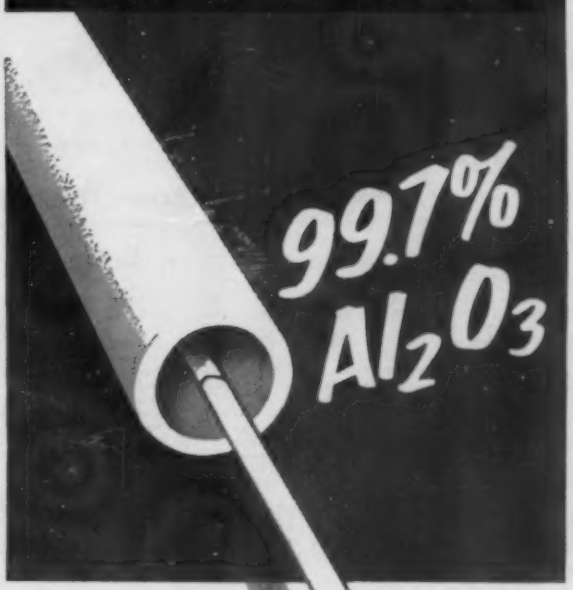

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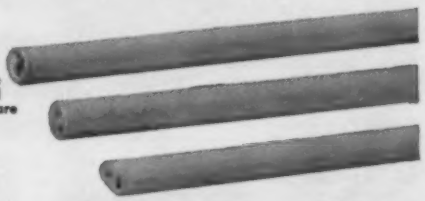

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• Index to Advertisers •

Abrasive Shot & Grit Co., Inc. 45
Acheson Colloids Co. ..... Back Cover
Ajax Electric Co. 118
Aldridge Industrial Oils, Inc. 162
Allegheny Ludlum Steel Corp. 49
Allied Research Products, Inc. 218
Allis-Chalmers 229
Alloy Engineering & Casting Co. 237
Alpha Molykote Corp. 166
American Brass Co. 133
American Bridge Co. 199
American Cyanamid Co. 96C
American Gas Furnace Co. 170
American Machine & Metals, Inc. 22
American Society for Metals 217, 238, 245
Amersil Co., Inc., Engelhard Industries 176
Ampco Metal, Inc. 125
Apothecaries Hall Co. 191
Armour & Co., Ammonia Div. 119
Armstrong-Blum Mfg. Co. 200
Ashworth Brothers, Inc. 186
Associated Spring Corp.,
Wallace Barnes Steel Div. 62
Atlas Mineral Products Co. 122

Babcock & Wilcox,
Tubular Products, Inc. 48
Baker & Adamson, General Chemical Div.,
Allied Chemical & Dye Corp. 149
Baldwin-Lima-Hamilton,
Electronics & Instrumentation Div. 174
Barber-Colman Co.,
Wheelco Instruments Div. 48B
Bausch & Lomb Optical Co. 96D
Bethlehem Steel Co. 171, 221
Blaw-Knox Co. 208
Branson Ultrasonics Corp. 165
Bristol Co. 20, 247
Brooks & Perkins, Inc. 172
Budd Co. 60
Buehler, Ltd. 129

Cambridge Wire Cloth Co. 116
Carborundum Co. 235
Carl Mayer Corp. 246
Chase Co., W. M. 136
Chromalloy Corp. 162
Cincinnati Milling Machine Co. 36
Cincinnati Sub-Zero Products Co. 160
Circo Equipment Corp. 167
Clark Instrument Co. 188
Cleveland-Cliffs Iron Co. 243
Cleveland Hard Facing, Inc. 24
Cleveland Metal Abrasive Co. 190
Columbia-National Corp. 17
Cooley Electric Mfg. Co. 202
Copperweld Steel Co.,
Ohio Seamless Tube Div. 141
Crucible Steel Co. of America
..... 115, 123, 127, 193, 227

Despatch Oven Co. 21
Detroit Electric Furnace Div.,
Kuhlman Electric Co. 176
Dietert Co., Harry W. 172
Dow Chemical Co. 203
Drever Co. 151
Driver-Harris Co. 131
Du-Lite Chemical Corp. 169

Eclipse Fuel Engineering Co. 225
Electric Furnace Co. ..... Inside Back Cover
Electro Alloys Div.,
American Brake Shoe Co. 2
Electro Metallurgical Co.,
Unit of Union Carbide & Carbon Corp. 117
Engineered Precision Casting Co. 168
Erico Products, Inc. 168
Ethyl Corp. 54

Fahralloy Co. 63
Federated Metals, Div. of
American Smelting & Refining Co. 134
Fenn Mfg. Co. 32
Ferro Corp. 167
Finkl & Sons Co., A. 159
Foote Mineral Co. 150
Formed Steel Tube Institute 19
Foxboro Co. 226

General Alloys Co. 233
General Electric Co. 56-57, 143, 153, 230
General Extrusions, Inc. 168
General Ultrasonics Co. 178
Globe Steel Abrasive Co. 156
Glo-Quartz Electric Heater Co., Inc. 166
Gordon Co., Claud S. 178
Great Lakes Carbon Corp. 177
Great Lakes Steel Corp. 50-51
Gries Industries, Inc. 166
Gulf Oil Corp. 8-9

Haller, Inc. 163
Harnischfeger Corp. 207
Harper Electric Furnace Corp. 148
Harrop Ceramic Service Co. 244
Haynes Stellite Co., Unit of
Union Carbide & Carbon Corp. 10-11
Hevi Duty Electric Co. 194, 195
Hill Acme Co. 231
Holcroft & Co. 46A
Holden, A. F., Co. 163
Hones, Inc., Chas. A. 180
Hooker Electrochemical Co. 210
Hoover Corp. 167
Hoskins Mfg. Co. 173
Houghton & Co., E. F. 205

Inductotherm Corp. 161
Industrial Heating Equipment Co. 29
International Nickel Co. 96A, 211
Ipsen Industries, Inc. ..... 128 A-B

Jelliff, C. O., Mfg. Corp. 165
Jessop Steel Co. 183
Jones & Laughlin Steel Corp. 137

Kemp Mfg. Co. 30
Kent Cliff Laboratories Div.,
Torsion Balance Co. 166
Kolene Corp. 128
Kux Machine Co. 32B

L & L Mfg. Co. 161
Leeds & Northrup Co. 223
Leiman Bros., Inc. 246
Lepel High Frequency Labs. 130
Lindberg Engineering Co. 121, 209
Linde Air Products Co., Unit of
Union Carbide & Carbon Corp. 204
Little Falls Alloys, Inc. 169
Loftus Engineering Co. 25
Los Alamos Scientific Laboratory
of the University of California 135
Lucifer Furnaces, Inc. 161

Machlett Laboratories, Inc. 157
Magnethermic Corp. 47
Magnetic Analysis Corp. 164
Mahon Co., R. C. 42
Malleable Founders' Society 120
Mallory-Sharon
Titanium Corp. ..... Inside Front Cover
Markal Co. 46
Maurath Inc. 168
McDanel Refractory Porcelain Co. 44
Mercoid Corp. 164
Metal & Thermit Corp. 220
Metal Treating Equipment Exchange, Inc. 161
Metal Treating Institute 40
Minneapolis-Honeywell Regulator Co. 54-55
Mixing Equipment Co., Inc. 154
Morehouse Machine Co. 163
Morganite, Inc. 247

National Forge & Ordnance Co. 236
National Research Corp. 14-15
National Metal Abrasive Co. 224
Niagara Blower Co. 136
North American Aviation, Inc.,
Atomics International Div. 146
North American Mfg. Co. 189
Northwest Chemical Co. 181
Norton Co. 18

Oakite Products, Inc. 206
Ohio Crankshaft Co. 147
Ohio Seamless Tube Div. of
Copperweld Steel Co. 141

Pacific Scientific Co. 61
Pangborn Corp. 33, 145
Penny Equipment Co. 39
Pittsburgh Lectrodryer Div. 38
Pittsburgh Plate Glass Co. 246
Pressed Steel Co. 198
Production Specialties, Inc. 162, 169

R-S Furnace Co., Inc. 182
Randall Mfg. Co., Inc. 161
Republic Steel Corp. 58-59
Riehle Testing Machine Div.,
American Machine & Metals, Inc. 22
Rigidized Metals Corp. 168
Riverside-Alloy Metal Div.,
H. K. Porter Co., Inc. 142
Rockwell Co., W. S. 188
Roll Formed Products Co. 167
Rolock, Inc. 152
Roto-Finish Co. 215
Rubicon Co. 45
Ryerson & Son, Inc., Jos. T. 64

Sandia Corp. 180
Sandusky Foundry & Machine Co. 16
Selas Corp. of America 216
Sel-Rex Corp. 166
Sentry Co. 196
Sharon Steel Corp. 155
Sheffield Corp. 39
Shore Instrument & Mfg. Co., Inc. 163
Sieburg Industries, Inc. 166
Sinclair Refining Co. 185
Solventol Chemical Products, Inc. 165
Somers Brass Co., Inc. 182
Standard Steel Treating Co. 43
Stanwood Corp. 162
Star Stainless Screw Co. 169
Steel City Testing Machines, Inc. 5
F. J. Stokes Corp. 212
Sun Oil Co. 26-27
Sunbeam Corp. 197
Superior Steel Corp. 32A
Superior Tube Co. 35
Surface Combustion Corp. 6-7
Swift Industrial Chemical Co. 167
Sylvania Electric Products, Inc. 175

Taber Instrument Corp. 163
Technic, Inc. 165
Thermal Research & Engineering Corp. 124
Thermo Electric Co., Inc. 41
Timken Roller Bearing Co. 4
Titanium Metals Corp. of America 179
Torsion Balance Co. 41
Turco Products, Inc. 139

Uddeholm Co. of America, Inc. 222
Union Carbide & Carbon Corp. 10-11, 117, 204
Unit Process Assemblies, Inc. 164
Unitcast Corp. 140
United Scientific Co. 213
U.S. Industrial Chemicals Co. 234
United States Steel Corp. ..... 16 A-D
USS Alloy Steel 16A
USS Forgings 16B-C
USS Lumnite Div. 16D
USS Oil Well Supply 244
Upton Electric Furnace Co. 184
Utica Drop Forge & Tool Corp. 228

Vacuum Metals, Inc. 214
Van der Horst Corp. 31
Vanadium-Alloys Steel Co. 201
Vanadium Corp. of America 187

Waltz Furnace Co. 144
Wankee Engineering Co. 244
West Instrument Corp. 28
Westalloy Div. 192
Westinghouse Electric Corp. 12-13, 52-53, 232
Wheelco Instruments Div.,
Barber-Colman Co. 48B
Wheelock, Lovejoy & Co., Inc. 132
White Metal Rolling and Stamping Corp. 169
Wilson Mechanical Instruments Div.,
American Chain & Cable 186, 198
Wiretex Mfg. Co. 162

Yoder Co. 191
Youngstown Sheet & Tube Co. 219
Youngstown Welding & Engineering Co. 169

Zaco Laboratories 164

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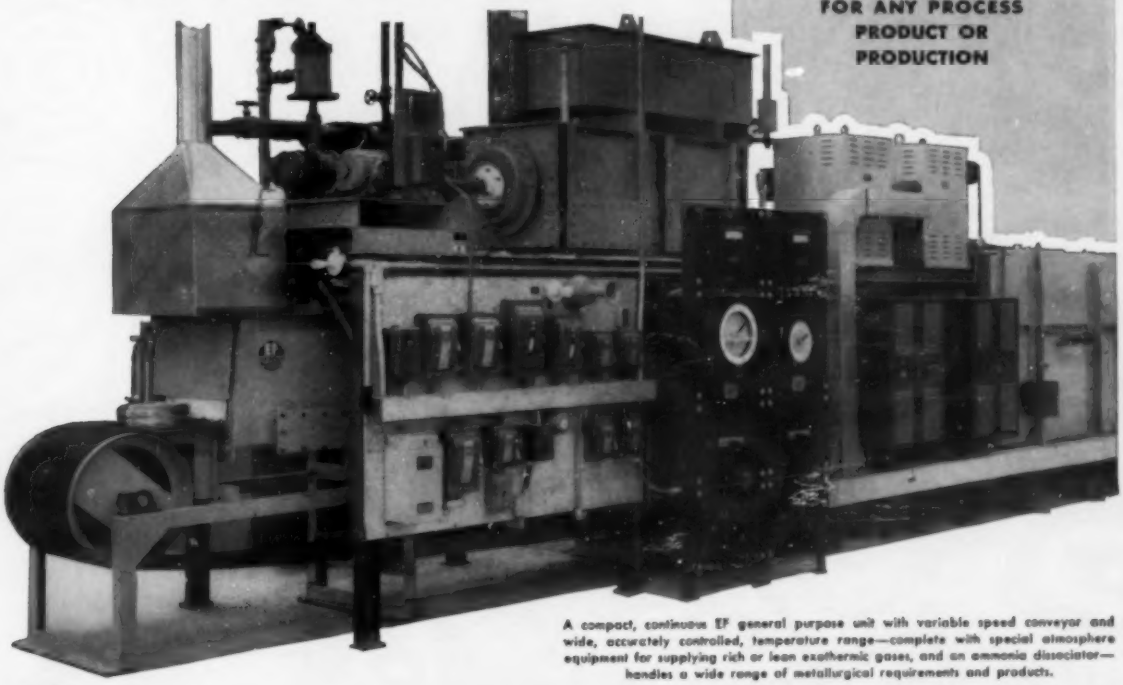

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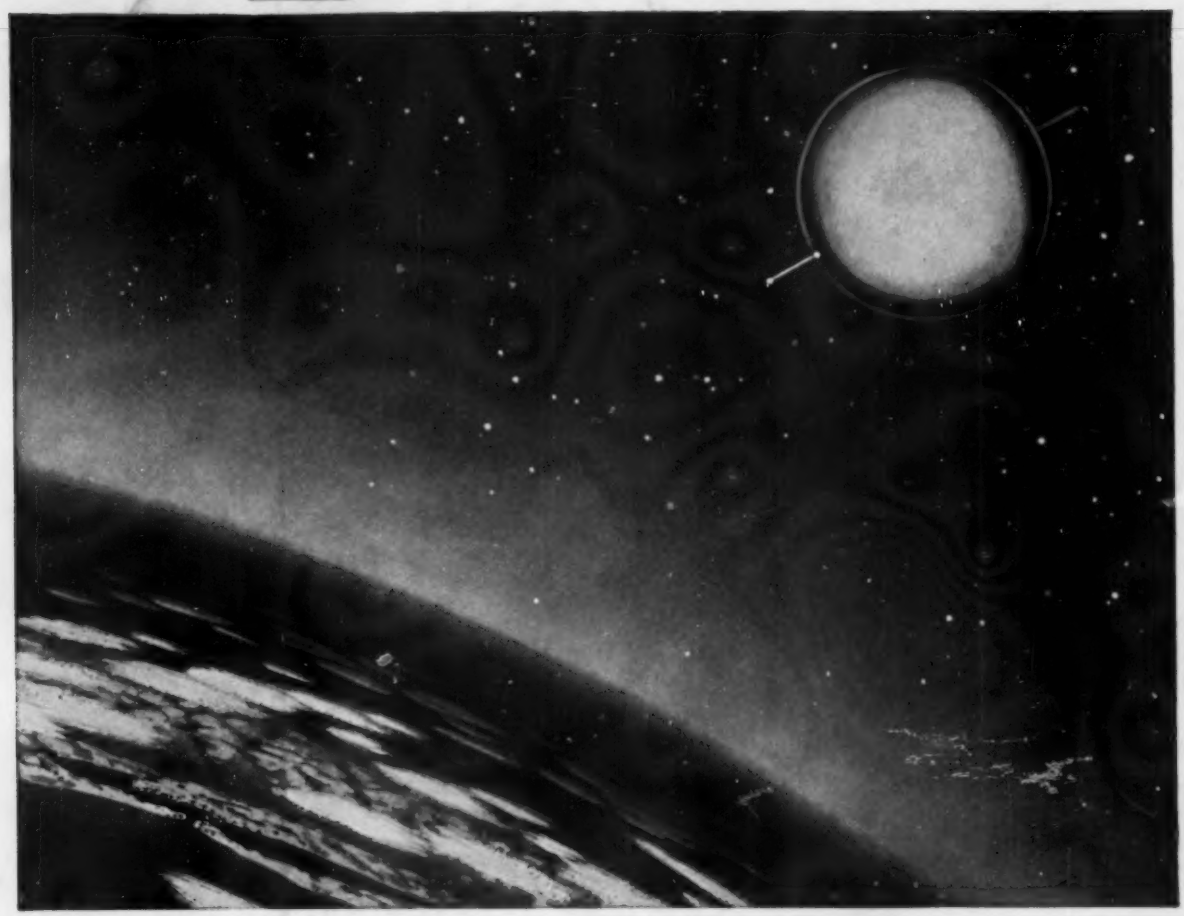

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